

DEVELOPMENT OF AN ORANGE PEELER



ATANDA, EMMANUEL OLUGBENGA

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ATANDA, EMMANUEL OLUGBENGA MNIAE, MNIFST

AGE / 99 / 3237

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CERTIFICATION

This is to certify that this is an independent research project carried out by **ATANDA, EMMANUEL OLUGBENGA (AGE / 99 / 3237)** in the department of Agricultural Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Nigeria. This thesis report is approved and accepted as meeting the requirements in partial fulfillment for the award of Master of Engineering in Agricultural Engineering (Agricultural power and Machinery option).

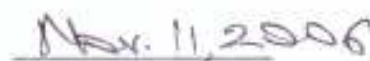


Engr (Prof). O.C. Ademosun

FNIAE, FNSE, FNIEM, COREN Regd

Professor of Agricultural Engineering

(Project Supervisor)



Date

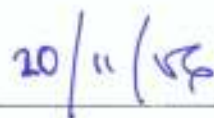


Engr. (Prof). A. A. Olufayo

MNIAE, MNSE, COREN Regd

Professor of Agricultural Engineering

(Head of Department)



Date

DEDICATION

This project work is dedicated to our Lord Jesus Christ through whom the Almighty father gave me the grace and ingenuity to carry out this research work. May His name be adored and praise forever.



DECLARATION

I hereby declare that this thesis is a record of my research work carried out in the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. It has neither been presented nor accepted in any previous application for a higher degree programme in any institution. All sources of information have been specifically acknowledged.

Atanda E. O.

Atanda. E. O.

Nov. 10, 2006

Date

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NOMENCLATURE

SPECIFICATION FOR GENEVA MECHANISM



SYMBOL	DEFINITION	UNIT
n_d	Speed of the Geneva wheel	rpm
z	Number of slot on the Geneva wheel	
n	Speed of the pin wheel	rpm
α	Semi indexing angle (Geneva wheel)	degree
β	Semi indexing angle (pin wheel)	degree
ϵ	Gear ratio	
μ	Radius ratio	
ψ	Angle of locking position	degree
V	Indexing time ratio	
e	Centre distance	mm
d_w	Diameter of Geneva wheel shaft	mm
r	Radius of pin wheel	mm
θ	Angular position of crank at anytime t	rad
ω	Angular velocity of pin wheel assumed to be constant	rad/s
ω_d	Angular velocity of Geneva wheel	rad/s
θ_{max}	Angular position of crank at which the product ($\omega_d \times d$) is maximum	degree
α_d	Angular acceleration of Geneva wheel	rad/s

αd_{ω}	Angular acceleration of Geneva wheel on the driven shaft	rad/s^2
t	Time taken for one complete rotation of pin wheel	s
t_i	Time for indexing	s
t_r	Resting time	s
R	Radius of the Geneva wheel	mm
r_p	Radius of the driver pin	mm
$\hat{R}$	Corrected outside radius of Geneva wheel	mm
S	Pitch circle radius of Geneva wheel slot	mm

SPECIFICATION FOR THE POWER TRANSMISSION SHAFTING

M_t	Torsional moment acting on the shaft	Nm
S_s	allowable shear stress for shaft without key way	MN/m^2
K_b	Combined shock and fatigue factor applied to bending moment	
M_b	Bending moment	Nm
n	Factor of safety	

ABSTRACT

An orange peeler was developed with a view to mechanize the operation of orange peeling unit and remove the drudgery involved in manual peeling. Prior to machine development, measurement of physical dimensions of sweet orange was carried out. Also an experiment was carried out to study the effect of oranges of different degrees of ripeness on the peeling force. Based on these data, an orange peeler which applies the intermittent motion of Geneva and Scotch yoke mechanisms was designed. The materials for fabrication of component were selected from available local materials. The various components were carefully assembled together and the total cost of machine production amounted to twenty-nine thousand and one hundred and forty naira (N29, 140.00). The machine was tested and the materials for the mating members were functioning as there was no break in transmission between them during operation. The machine was also tested for peeling oranges of different degrees of ripeness. The result shows that the machine capacity and functional efficiency obtained for yellow samples of oranges were 5.82Kg/h and 70.2%, the machine capacity and functional efficiency obtained for pale yellow samples of orange were 5.45Kg/h and 67.9%, and the machine capacity and functional efficiency obtained for green samples of orange were 5.41Kg/h and 72.7%.

CHAPTER ONE

INTRODUCTION



1.1 GENERAL

Oranges, lemons, grape fruits and lime are the fruits belonging to the citrus genus. The sweet orange (*Citrus sinensis*) is the most widely grown of the citrus trees and the fruits are either eaten fresh or made into orange juice (Ihekoronye and Ngoddy, 1985). At the time of harvest, they are still physiologically active with high rate of respiration, transpiration and oxidation. Thus, they are prone to rapid post-harvest deterioration and losses of about 30 to 60 percent under the tropical conditions of high temperature and relative humidity (Taylor, 1998). The changes that occur in harvested unprocessed fruits include water loss, conversion of sugar to starch, flavour changes, colour change, depreciation of the vitamin content, softening, decay and consequent loss in quality and quantity (Adewumi, 1999).

Therefore fruits need to be carefully handled, carefully processed, effectively packed and well stored at glut seasons to reduce nutritional and financial losses as well as maintaining their availability all year round (Olowonibi and Ozumba, 1999). Post harvest handling is considered a major problem in the growth of fruit processing industry in Nigeria. The post-harvest handling of fruits include sorting, washing, rinsing, peeling, cutting or slicing, pulping/juice extraction and sieving,

filtering/straining, mixing of non- fruit ingredients, heat treatments like boiling and pasteurization (UNIFEM/IT, 1988; Ademosun et al., 2002).

Of all these activities, peeling has so far proved very difficult. Manual method of peeling orange is still very common in Nigeria. This method involves the use of sharp objects like knife, cutlass and at times the use of teeth to remove the thick outer skin before consumption. This method is found to be very slow, laborious, time consuming, ineffective and lack the ability to take care of future increase in production that would be necessitated by the high demand for orange produces. Indications are that this manual method would remain in use for many more years, if a peeler is not developed.

In Nigeria, peeling constitutes a serious bottleneck in orange processing both at the peasant and industrial levels of operation. Most orange processing factories in Nigeria still peel manually. This manual method does not augur well for the growing labour cost of peeling and increasing population demand for orange consumption due to its nutritional values as major contributors of vitamins and minerals for human diets. The need to remove the thick outer skin from the orange therefore becomes obvious for the purpose of developing a peeler in the continuing effort to tackle the persistent problem of mechanizing the orange peeling unit operation in Nigeria.

2 OBJECTIVES OF THE PROJECT

The specific objectives are to:

design an orange peeler ;

fabricate and assemble the machine ;

test the machine.

3 JUSTIFICATION OF THE STUDY

Fruits are produced in large quantities in the tropics as a result of the favourable climate (Adewumi, 1999). During the peak periods, about 50 percent of the fruits harvested is lost as wastes (RAIDS, 1989; Ademosun et al., 2002). Apart from the loss of earnings due to wastage, the rotting of the fruits leads to environmental pollution (Ademosun et al., 2002). Existing manual peeling techniques for fruits like orange lead to drudgery, wastage and also consume a lot of time

Also, labour cost of peeling and increasing demand for orange produces make manual peeling extremely difficult to meet industrial needs. Contrary to what obtains in the Western countries where quite a number of works has been done to increase the production, processing and preservation of citrus fruits, very little work has been done to develop machinery for fruit processing in the third world countries (Taiwo, 1996 and Adewumi, 1999). Majority of the processing equipment used in the food industry in the developing countries are imported (Taiwo, 1996 and Adewumi, 1999).

Existing imported peeling machines are very expensive and not affordable to small and medium scale fruit processing factories in Nigeria. Ademosun (1997 and 2002) observed that industries established with imported technology do not function for a long period of time because of lack of spare parts, inadequate maintenance and inability to satisfy some local factors. He recommended that government should, therefore, discourage the use of imported technology. Such action he further opined will serve as an impetus for the rapid growth of indigenous technology.

It is therefore essential to evolve indigenous technology to address the issue of food processing in Nigeria. Many authors have reported on the need to develop indigenous technology in the various aspects of our agricultural operations (Makanjuola, 1994; Odigboh and Onwualu, 1994; Odigboh, 1995; Ademosun, 1997 & 2002; Adewumi, 1998; Babatunde, 1998; Olukunle, 2002; Ademosun et al., 2003; Ogunlowo, 2003; Agbetoye, 2003 & 2004). Presently, there is no commercial indigenous peeler for orange processing at both domestic and industrial levels of operation in Nigeria. This is the time to make appreciable contribution and progress towards the development of a peeler for orange.

CHAPTER TWO

LITERATURE REVIEW



2.1 ORIGIN, DISTRIBUTION AND BOTANY OF CITRUS FRUITS

Citrus fruits originated from the sub-tropical regions of Eastern Asia and the main centre of citrus production in the world include South Africa, Israel, Brazil, Spain, Japan, Italy and Mexico with United States of America as the largest producer (Rice et al., 1986). In Africa, large-scale producers are Mozambique and Swaziland (Rice et al., 1986).

Various varieties of fruit grow in tropical Africa, the most common ones are the citrus family, which include the orange, lemon, grapefruit, lime and tangerine. Other fruit varieties grown in tropical Africa include mango, pawpaw, banana, water melon, passion fruit, pine-apple, avocado, guava, sweet and sour sop, cashew and sapodilla (Kordylas, 1990). Fruits such as oranges, pineapples, bananas and mangoes are plentiful in the Southern and Middle belts of Nigeria (Ademosun et al., 2002).

Citrus as a group, are characterized by slender membranous pulp sacks inside the fruit. These sacks are filled with fluid and fill the space inside the fruit segment not occupied by seeds. Each fruit is covered with thick leathery peel, which protects it from injury and keeps the pulp in a sanitary condition. The peel is covered with a thick waxy skin with breathing pores. There are oil glands embedded in the tissue peel, which are kept under pressure by the swollen condition of the

surrounding cells. During ripening, the chlorophyll breaks down and other pigments become dormant, causing the fluid to change from green to yellow and, in the case of some citrus fruits to orange (Kordylas, 1990).

The colour formation is better in cooler climates, remaining more greenish in the tropics. The mesocarp or the inner colourless section of the peel is composed of elongated branched cells with large spaces between them. It is rich in sugars, pectin, vitamin C (about 46 percent), and other compounds. The endocarp consists of a thin transparent membrane surrounding the inside segments. Multicellular hairs grow out from the inner segment walls and fill with juice (Kordylas, 1990). As the fruit develops, it produces slender pulp sacks, which fill the sectioned cavities, except for spaces occupied by seeds. The endocarp provides the edible portion of the fruit. The juice from citrus fruit contains sugar and acids, mainly citric acid. During ripening, the amount of acid decreases and there is an increase in sugars and aromatic substances. The proportion of acids and sugar usually varies with the type of fruit (Kordylas, 1990).

The number of seeds contained in each fruit varies according to the type of fruit. There are some varieties, which are completely seedless. Chemical compounds known as limonoids occur in citrus rinds, juice and seeds. They are responsible for the bitter taste in citrus juice, most notably in grape fruit juice. When the compounds are extracted

from ground citrus rind and seeds, diluted with water and sprayed onto plants, they discourage several types of insect caterpillar from feeding on the plants. The extract can be used as an insecticide to protect plants against the corn earworm, armyworm, tobacco-bud worm and the pink cotton boll worm (Kordylas, 1990).

Members of the citrus sub-group are lime, sour orange, lemon, pummelo, grape fruit, tangerine, sweet orange and mandarin (Kordylas, 1990).

2.2 SPECIES OF ORANGE

Nigeria has two widely accepted species of orange namely sweet orange (*citrus sinensis*) and grape fruit (*citrus paradises*) as identified by Akhigbe (1989). They are consumed mostly in fresh form when in season.

2.2.1 Grape fruit (*citrus paradises*)

Grape fruit are large, usually in the form of a globe, about 8 to 15cm in diameter. They are greenish or pale yellow when ripe. The rind is thinner than other citrus fruits and the pulp sacks or vesicles are smaller. The pulp may be pale yellow or pink. Grapefruit are eaten as fresh fruit and the juice is also extracted. The juice has a characteristic flavor with a mild bitterness (Kordylas, 1990).

2.2.2 Sweet orange (*Citrus sinensis*)

This is the most widely grown and important of all the members of the citrus group. The fruit is shaped into a sub-globe, about 4 to 12cm in diameter. The peel is 0.5cm thick and tightly adheres to the segments. Upon ripening, it changes into an orange colour, but often remains green or pale yellow in the tropics (Kordylas, 1990). The pulp is very juicy and slightly acidic. The central line is solid and it may contain no seeds or many seeds. The pulp may be pale yellow, orange or red, or red-streaked. It is eaten as fresh fruit. The juice is extracted and canned as orange juice. Essential oils are obtained from the plant, including the flowers and the leaves, and orange oil from the peel. Pectin is also obtained from the peel. The pulp remaining after the extraction of the juice is used as an animal feed (Kordylas, 1990).

2.3 HARVESTING AND HANDLING OF CITRUS FRUITS

"Readiness for harvest" is the term proposed in place of the terms "maturity", "ripeness", and so on (Mohsenin et al., 1965). It refers to that stage of fruit or vegetable development which will insure the attainment of acceptable edible quality at the time of use. The particular stage referred to is dependent upon the final use intended for the crop, the treatment received after harvest and the elapsed time between harvest and use. At the present time, almost all harvest decisions are based on purely subjective evaluations of the appearance, taste and /or texture of

the crop. Some harvest decisions are made from experience or statistical reviews of harvest date decisions made in previous years. The optimum harvest period for mechanical harvesting is the time at which both quality and resistance to bruising are high. The present subjective and statistical means would hardly be capable of determining such extracting constraints (Mohsenin, 1972)

Mechanical shakers have been developed, and fruits are either shaken to the ground and then picked up with a scoop or vacuum device or shaken into some type of cart or sled, which is moved from tree to tree. This device is designed to minimize damage as the fruit falls and this is still a significant loss (Douglas et al., 1983). Obviously, the intended market affects how the fruit is harvested – a fruit for fresh market is still hand picked. Fruit to be processed into juices or other products may tolerate the damage associated with mechanical harvesting. Trees must be protected during harvest. Both human pickers and machines can damage trees and reduce yields in subsequent years (Douglas et al., 1983).

Harvesting time depends on varieties and cultivars. Early varieties cannot be left on the tree very long without risking loss of quality, while late varieties usually improve the longer they stay on tree. Lemons are harvested throughout the year but orange and grapefruits have a fixed harvesting and marketing season from October / November to May / June in the Northern hemisphere and from April / May to November /

December in the Southern hemisphere for early and very late varieties (Wolfong,1970).

Certain crops do not mature uniformly so that a selective method of harvesting, although not desirable, might be necessary. The physical properties which can be exploited for selective harvesting are physical characteristics such as size, shape, colour, surface conditions and mechanical properties of the fruit such as resistance to pressure and strength of the attachment point to the parent plant (Mohsenin, 1972). For economic reasons, however, researchers are trying to avoid selective harvesting by the use of growth regulators and breeding practices in an attempt to develop crops of uniform shape, size, colour, firmness and ease of attachment. With the advent of mechanical harvesting, if there is any justification for selective harvesting, the growers argue, it is to develop a crop where farmers can harvest at two different intervals of times, so that equipment and labourer can be used more effectively (Mohsenin, 1972).

Fruits should be handled carefully to prevent bruising and pickers should wear gloves to minimize damage to the outer skin (Rice et al., 1986). After picking, fruits should be graded, washed and kept as cool as possible until processed, consumed or sold. Ideal storage temperature is between 4 to 6°C. Damaged fruits should be used immediately or discarded (Rice et al., 1986). The practice of harvesting perishable produce such as citrus by shaking the trees frequently

results in cuts and bruises which renders the produce more susceptible to physiological and pathological damage. The use of ladders and picking bags for harvesting from the trees has been recommended (Rice et al., 1986).

2.4 GENERAL CAUSES OF POST HARVEST LOSSES IN FRUITS AND VEGETABLES

Fruits and vegetables are, in the simplest terms living tissue in which two types of process continue at the same time (Kordylas, 1990). One is the constructive building of new tissue and the storing of reserve nutrients, and the other is a destructive breaking down of carbohydrates during respiration. Both of these activities are promoted by enzymes contained within the crop tissue. During rapid growth, the constructive building up processes overtakes the destructive losses of respiration. But as maturity approaches, an equilibrium point is reached. This is the point at which fruits and vegetables are at their best and should be harvested (Kordylas, 1990). After harvest and during storage, the destructive processes overtake the constructive one, leading to a reduction in the weight of plant tissue. The flavour, and palatability of certain fruits and vegetables may therefore be reduced by the time of consumption (Kordylas, 1990).

After harvest, fruits and vegetables undergo chemical changes, and may also undergo spoilage by bacteria, yeast and fungi. Typical

changes show up in texture, colour and flavour as well as respiratory activities. For example, many fruits are seen to change from green to yellow or red and become soft and sweet. Green vegetables, on the other hand, lose moisture, wilt or lose their green chlorophyll, and turn yellow. Fruit become sweet either due to the disappearance of acids or to the conversion of starch to sugar (Kordylas, 1990).

The major causes of wastage in fruits and vegetables are directly related to mechanical, physiological, or microbial damage, or insect attack. All these factors are interrelated. For example the severe bruising of oranges during harvest can lead to tissue breakdown at the point of injury. This physiological injury is likely to lead eventually to rotting by microbial action (Kordylas, 1990).

Many fruits and vegetables are highly perishable and need careful handling during harvesting and transport. Often they cannot be taken over long distances without efficient transport and marketing arrangements. Fruits and vegetables in transit within the African region often are badly packed. As too often, they are stacked up high on the hard floors of lorries or vans. At best they are lightly packed in sacks or baskets, perhaps lined with leaves (Kordylas, 1990). Such poor packaging leads to high losses. The fruit or vegetables on top rests heavily on the produce below, causing severe bruising, cracking or even crushing. Heat is also generated within the pile which encourages further rotting of the bruised or crushed produce. The heat generated

also accelerates the ripening of produce causing changes in texture and flavour. In the case of fruit that soften on ripening, surface disfigurement also arises. These activities lead to rapid post-harvest deterioration and heavy losses (Kordylas, 1990).

2.5 PHYSICAL AND MECHANICAL PROPERTIES OF ORANGE

A good knowledge of the engineering properties of agricultural material is essential for the design of efficient mechanical systems used in agricultural production (Hem 1981; Ghaly, 1985). The basic engineering properties exhibited by agricultural materials include physical, mechanical, thermal, optical, electrical and magnetic properties (Adewumi, 1997; Adewumi and Ayodele, 1997; Adewumi and Funmiluyi, 2001; Agbetoye, 1998a & 1998b & 2002; Agbetoye and Kolawole, 2002; Raji and Tanimoyo, 2004). These basic properties are widely applicable to the storage, packaging, handling, transportation and processing of agricultural material (Hall, 1979; Jayasena and Illangantiloke, 1986).

Physical and mechanical properties of orange as an agricultural material are helpful in designing post-harvest handling machines and equipment hence, it is very essential to have a good knowledge of them. Shape, size, volume, surface area, density, porosity, colour and appearance are some of the physical characteristics which are important in many problems associated with design of a specific

machine or analysis of the product in handling of the material (Sitkel, 1986; Adewumi and Oduwole, 1995).

The shape of an object gives the configuration of that object. Descriptive terms such as round, oblate, conical, oblong, oblique, elliptical and so on are used to describe shape. The size of an object helps to measure the dimension of an object. Axial dimension such as length, width and thickness are three important parameters that are used in describing the size of an object. Shape and size are inseparable in a physical object and both are necessary, if the object is to be satisfactorily described (Mohsenin, 1986). Most sweet oranges have some resemblance with spherical shapes while some have shapes which cannot be described by any geometrical shape. Sitkel (1986) stated that the functioning of many types of agricultural machine is influenced decisively by the shapes and sizes of the objects participating.

Harvested immature fruits ripen slowly and sometimes do not ripen properly. When immature fruits are packed with mature fruits, ripening is uneven among fruits in the same container thus requiring sorting (Oyerinde, 1997). In sorting fruits like oranges, the properties used could be one or combination of two or three of the followings: weight, size, shape and colour.

The mechanical properties of agricultural materials include rigidity, elasticity, plasticity, turgidity, hardness, compressive strength,

impact strength, shear strength, firmness, coefficient of friction, angle of internal repose and angle of internal friction. Special class of mechanical properties of agricultural materials include rheological properties such as creep and stress relaxation, hydrodynamic and aerodynamic properties (Mohsenin, 1986). The exact knowledge of some of these mechanical properties will enable Engineers to design and fabricate post-harvest system and machines to help in handling fruit like orange.

Firmness is useful in determining the degree of ripeness of fruit like orange. In Israel, a machine for estimating the firmness of fruit has been developed. The machine tests the reaction of the fruit to impact, checks its weight and gives an index of its firmness. Fruits are sorted according to this index (Nahir et al., 1993).

The need for knowledge of coefficient of friction of agricultural products on various surfaces has been recognized by many researchers of agricultural machinery. Friction of agricultural products against machine parts is one of the main causes of mechanical injuries to fruits and vegetables during handling. Knowledge of the coefficient of friction is also important in the design of production and handling equipment and in storage structures (Puchalski and Brusewitz, 1995).

2.6 MECHANICAL PROCESSING OF FRUITS

Mechanical processing of fruits and vegetables often requires the information on mechanical properties of the raw material. Peeling,

coring, pitting, juicing and compressing are examples of these mechanical operations (Mohsenin, 1972).

In Nigeria today, fruits processed into juice are in high demand. This resulted to the influx of the beverages market with different kinds of imported fruit juice like five alive, orange juice drink, lucozade boost tree top and so on(Olowonibi and Ozumba,1999). However, these imported juice drinks do not come in their natural forms. Therefore, they do not provide the necessary nutritive values (Olowonibi and Ozumba, 1999).

The development of appropriate machinery for fruit processing in Nigeria should be well researched, considering the enormous contribution of fruit to human diet. Also fruit juices have their best taste, aroma and colour when they are freshly expressed and marketed. Unfortunately, the commercial processing of sweet orange has not been fully exploited in Nigeria as it was observed that the rate of production and supply of sweet oranges are high at certain months, but become entirely or almost non-available for the rest of the year.

Ensuring adequate and regular consumption of fruits and vegetables often poses a great problem in view of their highly perishable nature. When this is compounded by the on going rapid urbanization and the demands for higher standards of living, their preservation becomes inevitable. One of the major solutions appears to be through increased use of processing techniques. It is therefore not

surprising that while industrial fruit and vegetable processing is anything but buoyant in Nigeria, the market demand for imported processed products has every appearance of being strong and under-supplied. In particular, statistics indicate that tomato paste enjoys as apparent consumption twice that of all other processed vegetables, while fruit juices represent nearly five times the volume of trade in all canned fruits (Adeyemi,1988).

Ademosun et al. (2002) stated that various mechanical operations involve in the fruit juice production include selection of fruits, sorting, washing and rinsing, peeling or cutting, halving (size reduction), juice extraction, sieving (sedimentation/filtration),juice formulation tactness, deaeration, homogenization, pasteurization, filling/packaging. Within these stages of fruit juice production is peeling which is a major operation that must be performed in fruit processing. It is also an important single operation that is generally required to hasten the extraction of juice in fruit.

A typical operation flow chart for the fruit juice production by Ademosun et al. (2002) is shown in Figure 1.

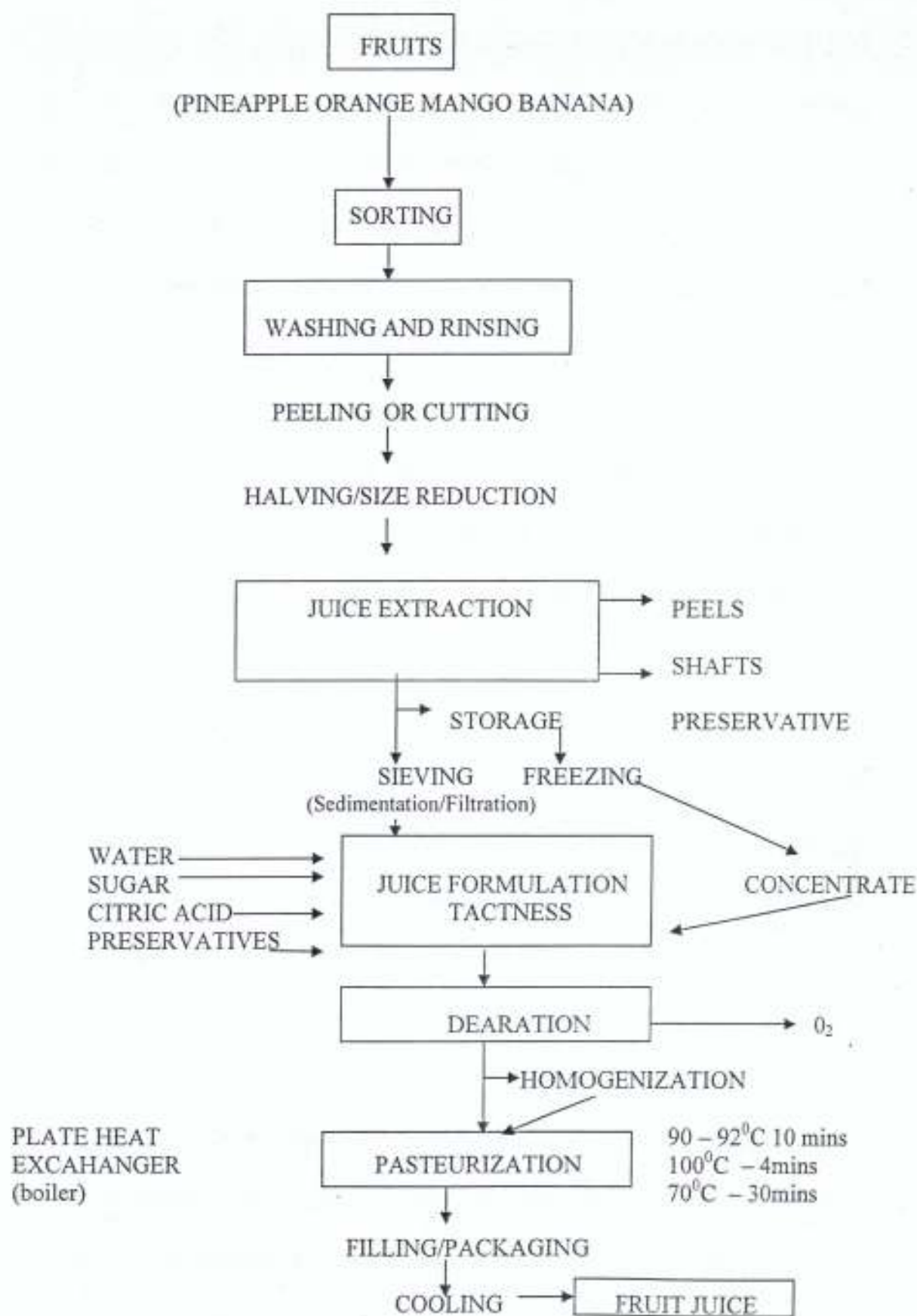


Figure 1: Flow Chart for fruit Juice Production
Source: Ademosun et al. 2002

Design of fruit processing machines for the establishment of a fruit juice factory will depend largely on the degree of processing operation to be carried out in the factory (Kaul and Egbo, 1985). An ideal fruit juice factory will have several machine units to carry out all the required operation for all the stages. These machines are sorter, washing machines, peeler and cutter, juice extractor or press, sieve, dearation, homogenizer, heat exchanger and packaging machine including canning or bottling machine (Ashaolu, 2001).

Ademosun et al. (2002) developed a model fruit juice processing plant for the medium scale fruit juice factory at the Federal University of Technology, Akure in Nigeria. The machine developed for the factory includes fruit washing machine, juice extractors, homogenizer, pasteurizer and heat exchanger. All the materials for fabricating the machines are available locally. The machines were well laid out in the processing factory. The factory was designed to produce 300 to 500 litres of raw juice that is 1000 litres of diluted juice per day of 8 working hours. All machines have been fully tested and they performed satisfactorily. The factory was commissioned on Thursday, 13th May, 1999 and is already in production (Ogunlowo et al., 2004). Citrus fruits like oranges are mostly peeled manually before juice expression; hence the development of an orange peeler is a timely intervention in the production line.

2.7 TECHNOLOGY OF PEELING

Generally, peeling involves the removal of a thin layer, which is called the peel, from a stock. The stock may be fruit, tuber, wood or even metal (Ukatu,1994). For cassava tuber, mechanization of the peeling process could be quite complex because cassava tuber vary widely in size and shape, thickness of peel, texture and strength of adhesion to the flesh (Ariavie and Ohowovoriole, 2002).

Also physical and mechanical properties of tuber vary significantly with age of root and season of harvesting (Ariavie and Ohowovoriole, 2002). In the same vein, Ukatu (2002) also stated that shapes and sizes of yam tuber are the bottlenecks in developing a yam-peeling machine. Coursey (1966) stated that the shape and size of yam tubers vary from species to species.

It is very important for researchers to consider some of these factors in developing peeling machines for agricultural materials which requires peeling. To make meaningful study on the development of an orange peeler, it is considered expedient to look into some agricultural crops that lend themselves to peeling. Such crops include potatoes, cassava, yam, ginger, onion and apple. The review of their processes is likely to assist one in selecting a particular technology that would be suitable for orange peeling.

2.7.1 Potato Peeling

Peeling is perhaps the second most important step in processing potatoes; the most important step being the selection of raw materials (Talbert and Smith, 1975). Under ideal conditions, peeling would require removal of a very thin outer layer of the potato. It would leave no peel, eyes or other material to be removed by hand trimming; and above all, it would leave the newly exposed surface of the potato unchanged by contact with heat or chemicals. This ideal condition is never achieved in commercial operations (Talbert and Smith, 1975). Incoming potatoes are thoroughly washed in order to remove all sand and dirt. Any sand or dirt that is carried over into the peeling equipment will erode the gasket material of steam peeler, damage the pump of the lye, or greatly reduce the service life of abrasive peelers (Talbert and Smith, 1975).

There are four methods of peeling potatoes and other root vegetables namely, abrasive peeling; lye peeling; steam peeling and flame peeling or combination of heat and lye peeling (Radha, 1995). Other methods include brine peeling and oil peeling (Radha, 1995).

2.7.1.1 Abrasive peeling: Abrasive peelers are designed to contact uniformly the surface of the potatoes being peeled with abrasive discs or rolls in such a way as to remove the peel with as little peeling loss as possible. Batch-type peelers usually consist of a vertical cylindrical container for holding the potatoes, with a rotating disc forming the bottom. Turning of the disc rotates so that they contact the abrasive

surface, which may be on the disc or the sides or both. Provision is made for discharging the peeled potatoes from the bottom of the peeler.

2.7.1.2 Lye peeling: Lye peeling of potatoes combine the effect of chemical attack and thermal shock for loosening and softening the surface skin, blemishes, and eyes of potatoes to the extent that they may be rubbed or worked off by pressure spray washers. Two general procedures for lye peeling are in use. One method uses lye at temperature considerably above the starch gelatinization point of about 70°C . In the other, low temperature lye peeling, caustic solution ranging from 49°C to 71°C is used. Low temperature lye peeling depends on chemical decomposition, hydration and softening of the skin and surface components of the potato, using temperature that do not result in cooling or denaturing of the underlying potato flesh. The essence of low temperature lye peeling is in the reduction or the elimination of the cooked, denatured layer or heat ring on the peeled potato (Talbert and Smith, 1975).

Both low and high temperature lye peeling use similar equipment. Normally, longer contact time with the lye solution will be required when low temperatures are used. Longer contact time make possible more precise control of the process. With low temperature, it is necessary to have more rapid and uniform circulation of the lye solution through the mass of potatoes being peeled. The greater viscosity of the lye solution at low temperature increases the need for rapid circulation. Starch,

protein and other components that are dissolved in the lye solution further increase its viscosity (Talbert and Smith, 1975).

High temperature lye peeling is generally used by the larger potato processors. Talbert and Smith (1975) reported that this requires the immersion of the potatoes from two to six minutes in a solution containing 15 to 25% lye maintained at 88°C to 104°C. Optimum immersion times and peeling losses depend on the variety and age of the potatoes being peeled as well as concentration of caustic in the solution and its temperature. It has been reported that high temperature lye peeling is much more effective in penetrating and removing heavily blemished or diseased areas than in low temperature peeling.

During lye peeling, the entire surface of the potato, regardless of shape or eye positioning, is affected and softened equally by the action of the lye. The surface assumes a deep yellow colour due to the reaction of the lye with the normal constituents of the potato. Sludge is formed in the peeler as a result of chemical action of lye on potato tissues and subsequent loosening of this material as the potatoes pass through the peeler. This sludge is allowed to settle and is drawn off from the bottom of the peeler or lye storage tank or is removed by screens or other filtering devices. If the sludge is removed, the useful life of the lye solution is greatly extended. The concentration of the lye in solution should be checked periodically by titration with standard acid solution,

using phenolphthalein as an indicator. Lye is added as needed to maintain the desired concentration (Talbert and Smith, 1975).

If the lye affected surface is not removed immediately by vigorous washing, it soon hardens and becomes much more difficult to remove. Unless lye is washed off or neutralized, it continues to react with potato tissue. Any caustic not removed will result in subsequent yellowing of the surface of the potato due to reaction with naturally occurring flavones in the potato (Talbert and Smith, 1975). After washing, potatoes are sometimes sprayed or immersed in a dilute solution of sodium bisulfate or hydrochloric, citric, phosphoric or other acids. This will neutralize any residual caustic. Phenolphthalein turns pink when applied to the surface of a potato containing residual caustic and may be used in checking for completeness of lye removal.

The draper, rotary screw and mill-wheel or reel- type lye peelers are used in potato peeling plants. Each of these peelers is designed so as to submerge the potatoes in a heated lye solution and maintain them in this solution for a predetermined time. The draper belt is equipped with logs or other means of conveying potatoes through the peeling medium. The helical screw lye peeler advances the potatoes through a hot lye bath by the rotation of a screw conveyor operating in the caustic solution (Talbert and Smith, 1975).

The mill wheel-type lye peeler transports the potatoes through the lye peeling solution as the wheel rotates, the lower portion of the

wheel being in the lye solution. The potatoes are in effect carried through the hot lye as a succession of small batches held between flights (of a conveyor) on the periphery of the wheel. All points of friction on this peeler are free from contact with the lye solution. The solution is heated by steam coils in the peeler tank or by pumping the lye through external heating coils. Adequate circulation and agitation of the lye solution through and within the peeler tank is essential for good temperature control and uniform peeling (Talbert and Smith, 1975).

2.7.1.3 Steam peeling: It has been reported that steam peeling is a very satisfactory method for the removal of peels from potatoes. By this method, potatoes are subjected to high pressure steam for a short time. This causes hydration and cooking of the surface tissue, which softens, and loosens the peel from the underlying tissue. After adequate contact with the potatoes, the steam is released rapidly from the pressure vessel, the potatoes are discharged and the softened tissue is removed by brushes or water sprays. Since steam attacks all surfaces of potatoes uniformly, the contour or shape of the potato has little effect on the efficiency of peeling. Steam peeling, however, is not used at all in potato chip plants (Talbert and Smith, 1975).

Equipment used for steam peeling may be either continuous or batch type. For the latter, various sizes of pressure vessels are used. These are equipped with a quick-opening charging door and are usually mounted on hollow axles to permit rotation of the peelers during

operation and to allow for admission and discharge of steam. After charging with the proper amount of potatoes, the door is closed and steam is admitted until the desired steam pressure is attained. Venting is necessary for the removal of air from the retort if proper peeling temperature is to be obtained. Pressures up to 6.9 bar are used (Talbert and Smith, 1975). The retort is normally rocked or rotated slowly to ensure even distribution of steam through the charge and to aid in the removal of loose peel. The steam supply valve may be closed as the required temperature and pressure in the retort have been reached. As soon as the steam has been vented to the outside and atmosphere pressure attained, the retort is opened and the charge is dumped. The potatoes are then moved to the washer where cooked and softened tissues are removed.

2.7.1.4 Flame Peeling: Flame peeling makes maximum use of high temperature for removal of the skin from the potatoes by actual charring or carbonization. In flame peeling, potatoes are passed through a flame or refractory oven, which subjects all surfaces of the potato to about 1093°C for a period of 15 to 30 seconds. The short retention time greatly reduces the depth of the heat ring on the peeled product. It has been reported that peeling losses range from 3 to 16%, compared with abrasion peeling losses of 12 to 20% for the same lot of potatoes (Talbert and Smith, 1975).

In using flame peelers, difficulties are encountered in controlling temperature. They are noisy and require considerable maintenance and servicing. Flame peelers have not been used very widely for peeling potatoes but are used quite extensively for peeling onions (Talbert and Smith, 1975). The problem of conveying potatoes through the intensive heat of the furnace is the principal problem facing builders of flame peelers. Rotating drums, screws or rolls must be constructed of heat resistant material and must rotate the potatoes as they pass through flame or heated area. No matter what device is used for conveying the potatoes, its useful life is limited by the effects of high temperature. Fuel costs are high in consideration of the amount of work that is done. Although the major part of the outside peel can be removed by the flame peel-washer combination, deep set eyes and blemishes are not effectively removed (Talbert and Smith, 1975).

2.7.1.5 Brine Peeling: Brine solution maintained near the boiling and saturation points have been used for peeling potatoes, only on a limited scale. Since evaporation is constantly taking place, care must be exercised to prevent over-saturation and crystallization. Immersion times required for adequate peeling are reported to range from 3 to 10 minutes. The cost of salt for peeling a given amount of potatoes is estimated to be about 0.2 to 0.5 that of lye. Brine solutions present less of a hazard to operating personnel than lye but are corrosive to equipment. Any salt on the peeled product does not require neutralization and may reduce

enzymatic discoloration of the peeler surface. In some cases, lye and salt have been used together (Talbert and Smith, 1975).

2.7.1.6 Oil peeling: Heated oil at 150°C to 204°C has been used to remove the peel from potatoes. If mineral oils are used, they must be completely removed or undesirable oil odours will be imparted to the product. Vegetable oils have also been used. This is indeed a very expensive method of peeling (Talbert and Smith, 1975).

Generally, peeling losses vary with type of peeling, size and shape of potato, depth of eyes and length of storage time of the tubers. Smaller tubers have greater peeling losses than larger ones; newly harvested potatoes have less loss than older potatoes from storage since the peel thickness increases with age of tubers just like yam tuber (Ukatu, 1994).

2.7.2 Cassava Peeling

Odigboh (1976) designed, constructed and tested a continuous process cassava peeler. The technology used in the continuous type consists of cylindrical knife assembly and a solid cylinder, which are mounted parallel to each other and set at 20mm apart on an inclined frame. Cassava tubers, which were cut into pieces of 100mm long, were fed into the system. The cylinder with knives and the solid cylinder rotate clockwise at 200rpm and 88rpm respectively. The cassava pieces were pressed against the two cylinders. This made them rotate in the

opposite direction and as they moved down the inclination, the rotating knives progressively peeled them.

Odigboh (1985 & 1986) constructed a prototype batch peeler models 1 and 2. In the batch process cassava peeler, he used the abrasion peeling method. A drum, which was mounted eccentrically on a shaft was loaded with mixture of cassava tubers and some inert abrasive materials. This was later modified during operation as the drum was rotated at optimum speed of 40rpm. As the drum rotated, water was sprayed on to the roots. The complex side -to-side and up-and-down motions of the drum, resulting from eccentric mounting lead to the peeling of the roots.

Ohowovoriolè et al. (1988) developed a rotary cassava peeler. The technology used in the machine consists of a rotary outer frustum of a cone and a fixed inner cylinder mounted with cutting edges to peel the cassava tubers. Ariavie and Ohowovoriolè (2002) later modified Ohowovoriolè et al. (1988) rotary peeler due to some major problems encountered in the existing peeler. The technology they used was similar but with a bit of modification in the peeling chamber. The modified peeler is made of two-stage peeling chamber for effective peeling.

Itodo (1999) developed a manually operated cassava (*Manihot esculenta* Crantz) peeling machine. The technology of peeling used consists of brushes arranged on the circumference of a rotating drum, and brushes arranged on springs on the inside of concave to facilitate the peeling of irregular shaped roots. The cassava roots are peeled by the

scrubbing action of the brushes on the concave and the rotating drum when roots are introduced into the space between them.

2.7.3 Yam Peeling

Ukatu (1994) developed an industrial yam peeling and slicing machine. The peeling units of the machine consist of a conveyor system, which accepts unpeeled tuber, and deliver them to where they would be peeled and a peeling chamber where peeling takes place. Controlled abrasive peeling was considered and the only problem, however, is the browning effect. This browning phenomenon is also present in this method of peeling, since the method involve exposing the tuber flesh. The machine makes use of blades arranged to traverse round tuber to perform the peeling action. The blades can be adjusted to vary the depth of peeling.

2.7.4 Ginger Peeling

Jabar and Ali (1986) carried out the peeling of ginger by hand, gunny bag, lye and by sand blasting using fine sand at a pressure of 2 to 2.5kg/cm². It was observed initially that the peeling efficiency in hand peeling was 100% but after 2 to 3 hours of continuous peeling, the efficiency was reduced to 85-90%. The material loss was also increased from 2% to 5%. The capacity of peeling was 30kg/day (8hrs). Peeling by gunny bags was found to be faster but the efficiency was only 70%

because of the inability of gunny bag to enter into the grooves of ginger pawns. The capacity of peeling was 50Kg/day (8h) per labourer. The peeling efficiency of ginger by lye (sodium hydroxide) was also reported by Jabar and Ali (1986). Peeling method was increased from 42 to 70% by increasing the lye concentration from 1.0 to 20% and dip time from 10minutes to 30minutes at 70°C. The increased dip time did not affect efficiency. The material loss increased significantly from 1.35 to 15.3% maximum by increasing the temperature and concentration of lye and dip time of ginger. Peeling efficiency of 52% with 1-2% material loss was observed in sand blast peeling. This method could remove the skin from surfaces only and not from grooves.

Agrawal et al. (1987) developed an abrasive brush- type ginger peeling machine. The technology used consisted of two continuous brush belts being driven in opposite directions with a downward relative velocity by variable speed motor. The movement of the two brush belts in opposite directions provided the abrasive action on the ginger passing in between while the downward relative velocity provided the downward flow of ginger.

Radha et al. (1993) developed a low cost manually operated ginger peeling machine. Brushes made of coconut fibres were used in moving as well as on stationary abrasive surfaces. The hardness of coconut fibre results in better abrasive action while flexibility helps in cleaning the grooves or irregular surface of epicarpic layer.

Aniyi (1998) reported that the manual/ indigenous methods used in peeling are by rubbing the ginger on jute cloth and scrapping with bamboo knives after overnight soaking in water. The scrapped produce is washed and dried under the sun for 6 to 8 days and hand-rubbed (Aniyi, 1998). It is again stepped in water for 2 hours, dried and then rubbed to remove all the remaining bits of the peel. These methods are very laborious, time consuming and also causes high loss of material and quality. Sunlight also bleaches the product (Aniyi, 1998).

An abrasive brush-type ginger peeling machine was developed by Aniyi (2000). The operation of the machine is such that it consists of two continuous brush belts being driven in opposite directions with a downward relative velocity of a variable speed motor. The technology of peeling involves the movement of two brush-belts in opposite direction thereby providing the abrasive action on the ginger passing in between, while the downward relative velocity provides the downward flow of ginger. The spacing between the belts and the belt velocity could be varied.

2.7.5 Onion Peeling

Srivastava et al. (1997) stated that several methods have been used for peeling onions. The common method used in modern onion processing industry is lye treatment, flame peeling and mechanical peeling. They stated that lime and flame peeling methods are harsh and

not suitable for many onion products. Therefore, they recommended the mechanical peeling method (abrasive peeling). For their machine, they made use of four scoring blades as the peeling tool.

2.7.6 Apple Peeling

Hydrostatic compression of whole fruits such as apples, confined in a pressurized water chamber, loosens the skin so that the skin can be peeled off as in the case of a ripe peach. The high-pressure steam has already been investigated to assess its possibilities for peeling (Burkhardt et al., 1970). In cold-water hydrostatic compression, the optimal condition of pressure and time to resulting effective peeling without enzymatic darkening and excessive tissue breakdown under the skin are the problems to be investigated (Mohsenin, 1972).

2.8 EXISTING INDIGENOUS PEELING MACHINES

A great deal of research effort has been devoted to the development of indigenous peeling machines by many researchers and research institutes in different parts of the world. In order to make meaningful contribution towards the development of a peeler for orange, it is necessary to review some of the notable contributions to indigenous peelers that have been developed for some crops like cassava, yam, potato, ginger and onion.

2.8.1 Cassava Peelers

2.8.1.1 Continuous process cassava-peeling machine

Odigboh (1976) designed, constructed and also tested a continuous process cassava-peeling machine as shown in Figure 2. The cassava root pieces enter through one end of the machine unpeeled and comes out through the other end, peeled. The efficiency of the machine was 95% at 135 kg/h when handling sized pieces of cassava root. The advantages of this machine are that it has a high peeling efficiency and non-wastage of the root flesh. The disadvantages are that the machine is manually operated, some of the pieces not well peeled have to be sorted and re-peeled and also the labour involved in the slicing operation is intensive.

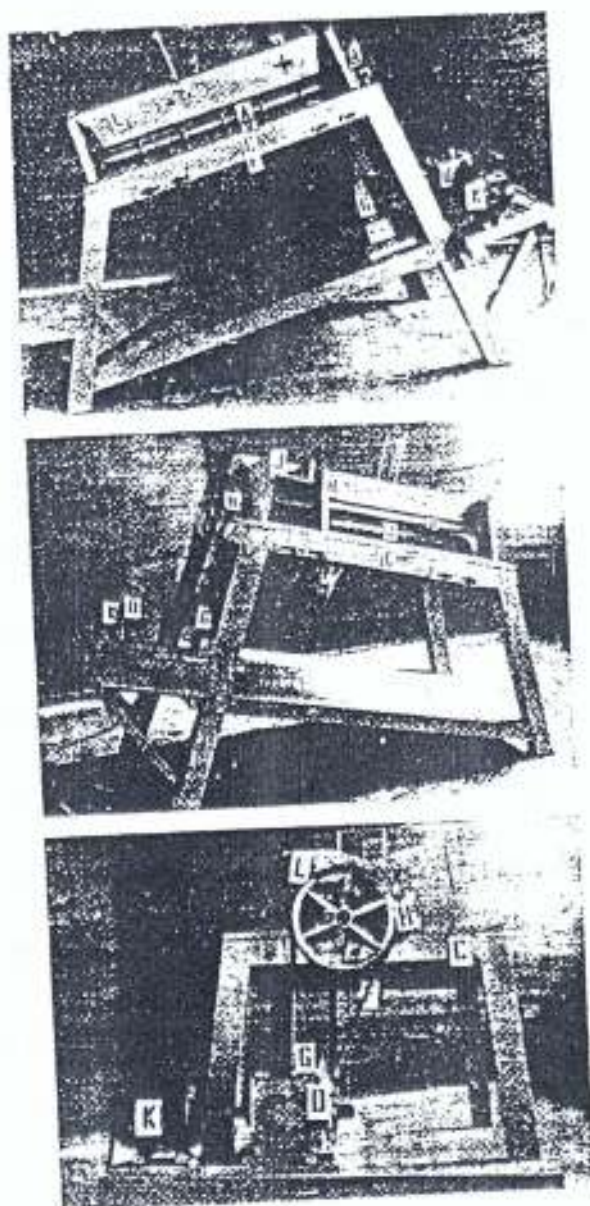


Figure 2: Continuous-process cassava peeling machine.
Source: Odigboh, 1976; Odigboh & Onwualu, 1994

2.8.1.2 The Model I batch cassava peeler

While evaluating the performance of the continuous- process cassava peeling machine, developed in 1975 as reported by Odigboh (1976), desirability of a cassava peeler, which can handle whole cassava tuber in bulk, without the necessity to cut or size them became evident. Consequently, the model I batch cassava peeler was subsequently developed in 1978.

It consists simply of a 210- litres oil drum, eccentrically mounted on a shaft, as shown in Figure 3. The drum is perforated with two holes of 3mm diameter per square cm on the drum surface. The inside surface of the drum is covered with a sheet of 5mmx5mm rhombic expanded metals, thereby presenting a roughened abrasive inside surface. A 200mmx150mm gate is provided at one end of the drum for loading and unloading the cassava tubers.

To operate, the cassava tubers and a predetermined quantity of some inert materials, such as quartziferous pebbles or pieces of hard quarry stone with maximum dimensions of between 3.2mm and 4.8mm, are loaded into the drum, which is then rotated at 40rpm, through a v-belt speed reduction system driven by a 0.56KW, 1440rpm electric motor. As the drum is rotated, the complex side-to-side and up-and-down shaking motions, resulting from the eccentric mounting of the drum, causes the cassava tubers to rub against the abrasive surface of the drum, the inert abrasive materials as well as one another. The

rubbing action progressively removes the peels from the cassava tubers, leading eventually to the complete and uniform peeling, irrespective of size or shapes of the cassava tubers.

As peeling progresses, water is sprayed onto the tubers and abrasives from the drum shaft, which is a 47.5mm diameter galvanized iron pipe, appropriately perforated for the purpose. The spray water washes off and carries away the finely abraded peels through the perforations in the drums, and thereby prevent fouling and dulling of the abrasive surfaces. The water of course simultaneously washes the peeled cassava tubers to give clean product which shows that the peeling achieved is so thorough that bothersome hand trimming is effectively eliminated. But the peeling rate is low, being a maximum of about 180 Kg/h when time spent for loading and unloading the tubers is discounted. The above fairly detailed description of the model 1 peeler earlier given elsewhere by Odigboh (1981) has been represented here because, the evolution of models II and III of the batch- process peeler consisted in the progressive refinements of the model I, the refinements being aimed principally at increasing the peeling rate.



Figure 3: Model I batch-process cassava peeler prototype
Source: Odigboh, 1991; Odigboh & Onwualu, 1994

2.8.1.3 The model II cassava peeler prototype

The basic technical features of the model II peeler developed in 1980 (Odigboh, 1985 & 1986) are essentially the same as those of model I. However, the drum of model II, built of 3mm-thick galvanized mild steel sheet and fashioned as shown in Figure 4, has a larger volumetric capacity—a bigger length-to-diameter ratio and a smaller weight per unit volume. Another important refinement or modification is that the eccentricity of mounting in the model II is less in model I. Also,

balls of expanded metal are used as the abrasive materials, instead of pieces of stones or pebbles.

The increased length-to-diameter ratio and the reduced eccentricity of mounting are both intended to increase the rate of abrasion by reducing the cascading of the mixture of cassava tubers and abrasives, thereby increasing the effective time of the rubbing action needed for peeling. The balls of expanded metals are lighter and more durable abrasives than the pebbles or the pieces of stone. The smaller weight per unit volume of the model II drum, coupled with the lighter weight of the expanded metal abrasive balls, means that more cassava tubers can be handled per unit volume. A 1.5KW electric motor is used to drive the model II peeler at 40rpm. Another advantage of the cage structure of the model II peeler is that it facilitates visual inspection of the cassava tuber while peeling is in progress. This helps to prevent over peeling or excessive loss of useful tuber flesh.

Apart from the indicated refinements or modifications, the model II peeler is operated in the same way as the model I and has similar peeling effectiveness. But the peeling rate is improved only to about 220Kg/h, which is still considered low.

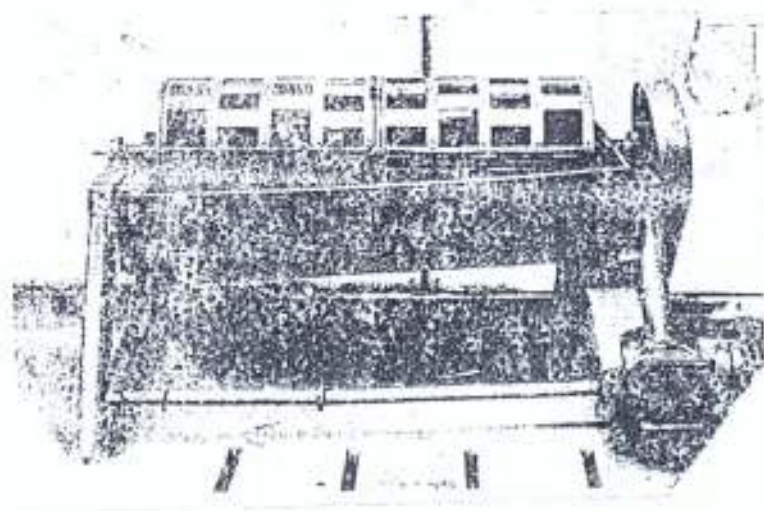


Figure 4: Model II Batch-process cassava peeler prototype
Source: Odigboh, 1991; Odigboh & Onwualu, 1994

2.8.1.4 The Model III Batch Cassava -Peeling Machine

The development of the model III batch cassava peeling machine as shown in Figure 5 was undertaken mainly to achieve further improvement in the peeling rate. In discussing the operating principles of the abrasion cassava peeler, Odigboh (1981) explained that the speed of rotation is critical for effective operation. The rotational speed of the drum must be such that the resultant centrifugal force does not exceed the weight of the cassava tubers or the abrasives, at any point in the drum. Otherwise, the tubers or the abrasives would be pressed against the inside surface of the rotating drum, and be carried round and round without the relative motion which is necessary to produce the rubbing action that does the peeling. Because of the eccentric mounting of the drum, different points

on the inside surface of the drum are at different radial accelerations, depending on their radial distance from the axis of drum rotation.

The model III peeler design seeks to get around this limitation on the rate of peeling imposed by the limitation on the drum rotational speed. It also embodies all the refinements and modifications introduced in the Model II peeler. The model III peeler consist of a drum of 5x5mm rhombic expanded metal, folded and attached to the inside surface of a cage framework of 21mm outside diameter mild steel pipes. The drum is mounted with the same eccentricity as the model II peeler, on a shaft which is fashioned from a 47.5mm diameter pipe. The special feature of the model III peeler is the provision of four abrasive cylinders of expanded metal, mounted inside the peeling drum and driven by a planetary gear arrangement to rotate about their axis at four times the rotational speed of the drum, while revolving with it at its rotational speed of 40rpm.

To operate, whole cassava tubers and appropriately proportioned quantity of abrasive balls of expanded metal are loaded into the drum which is then rotated at 40rpm, the complex shaking motions of the drum, together with the resultant faster rotation of the four abrasive cylinders, in addition to the fast bombardments of the abrasive balls of expanded metal, lead to rapid peeling of the cassava tubers. As earlier described for both models I and II, a controlled amount of water is continuously sprayed on to the peeling tubers to wash off and carry

continuously sprayed on to the peeling tubers to wash off and carry away the finely abraded peels and thus avoid fouling and dulling of the abrasive surfaces. The model III peeler achieves uniform and thorough peeling, irrespective of the sizes and shapes of the cassava tubers at a peeling rate of about 300Kg/h, discounting time spent in loading and unloading.

It is easy to appreciate the fact that the larger the quantity or the greater the force of the spray water, the more effective the peeling process. But the use of a continuous spray of a large quantity of water may pose a serious problem in rural areas where water is scarce or pipe-borne water may not be available. In any event, it may be necessary to make provisions to filter and reuse the water in a cycle, to reduce both the cost and the disposal problem of the process water. An alternative to continuous spray of water is to use a water bath, filled to a level such that the peeling drum just skims the water as it rotates.

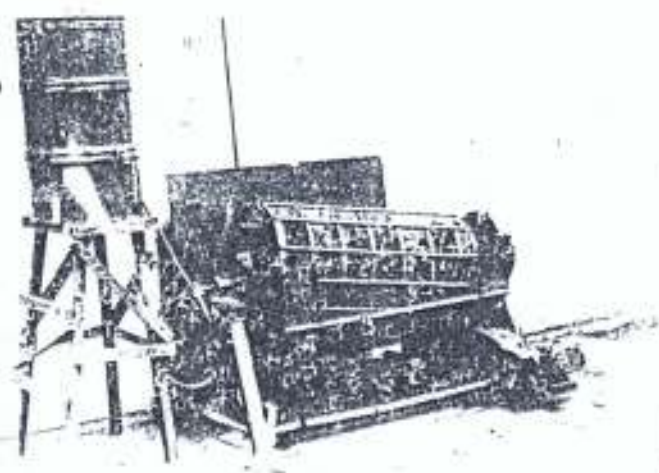


Figure 5: Model III Batch-process cassava peeler prototype
Source: Odigboh, 1991; Odigboh & Onwualu, 1994

2.8.1.5 Ohowovoriole et al. rotary cassava tuber peeling machine

Ohowovoriole et al. rotary cassava peeler (1988) is aimed at improving effectiveness and peeling rate. The design as shown in Figure 6 consists of a rotary outer frustum of a cone and a fixed inner cylinder mounted with cutting edges. The outer frustum of a cone consists of a small circular end plate (A) and a big circular end plate (B). Two – end shafts (D) running through the two – end plates eccentrically are fixed to the inner cylinder with longitudinal cutting blade (E). The end shafts are mounted on adjustable bearing housing (F) to allow for variation of eccentricity between the cylinders and the conical surfaces. The bearing carrying the shafts are mounted on frame (G). A pulley (H) is mounted near the big end plate from which a motor drives the shaft and inner cylinder assembly through a belt drive. Some major deficiencies encountered in the existing Ohowovoriole et al. rotary cassava peeler include:

- (i) Reduced peeling efficiency with increased peeler usage.
- (ii) Varying peeling effectiveness with tuber diameters and usage.
- (iii) Crushing of an increasing number of cassava tubers with increased use of machine.
- (iv) Rusting of cutting blades.
- (v) Feeding difficulties of tubers.

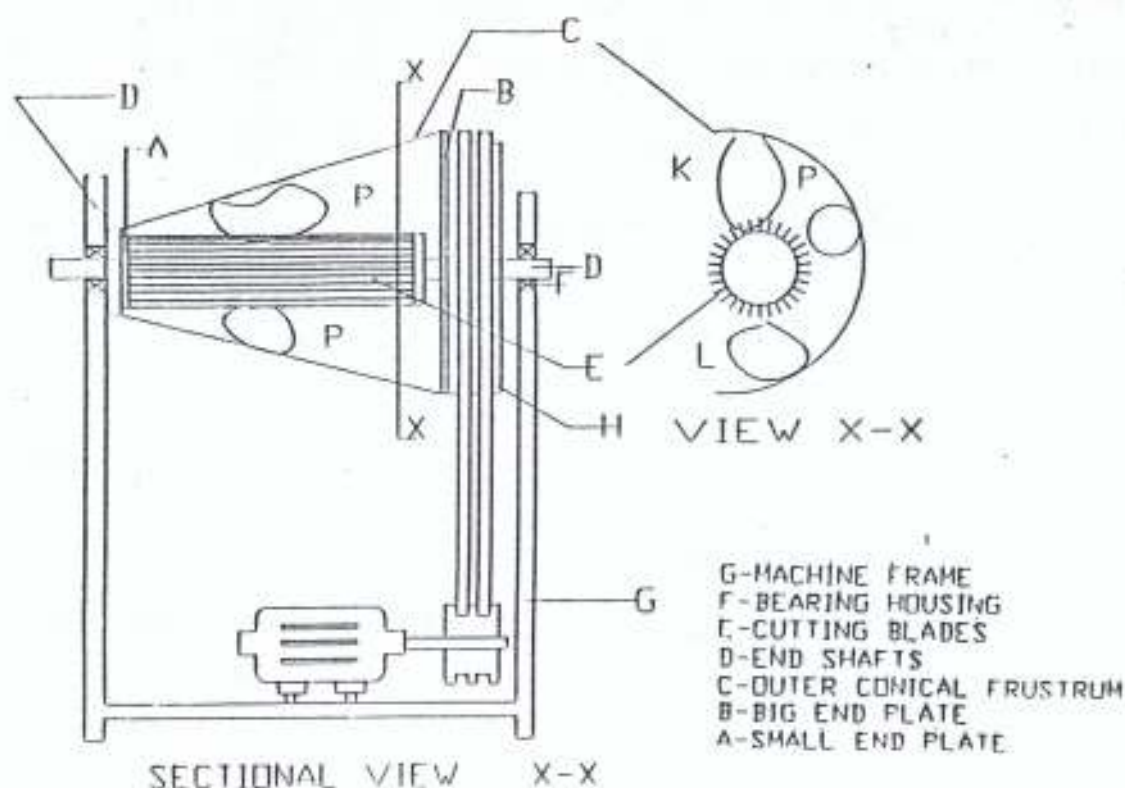


Figure 6: Original Ohowovoriol's Rotary peeling machine
 Source: Ohowovoriol et al. 1988

2.8.1.6 Improved Ohowovoriol et al. rotary cassava tuber peeling machine

Ariavie and Ohowovoriol (2002) later modified Ohowovoriol et al. (1988) rotary cassava peeler. The modified peeler as shown in Figure 7 is made of two stage peeling chambers for effective peeling. In the operation of the machine, unpeeled slices are fed into the peeling chamber P between the fixed inner cutting knives D and outer rotating frustum of cone lined two- third internally with grating surface, with the remaining one-third serving as inlet feed. The slices in the peeling section are shown in the sectioned view for clarity even though they

would not normally be visible in the sectioned view X-X. Stage two of the peeling consists of a rotating shaft, L lined with iron wire gauze surface in a stationary cylindrical casing sloped at 15° (determined by experiment). This is done to effect complete peeling of tubers as it rolls towards the exit of the tumbling section M.

An improvement in terms of peeling effectiveness and a reduction in waste of useful flesh obtained from this redesign of the cassava-peeler is obtained. The improved prototype has thus solved some of the inherent problems existing in the earlier design.

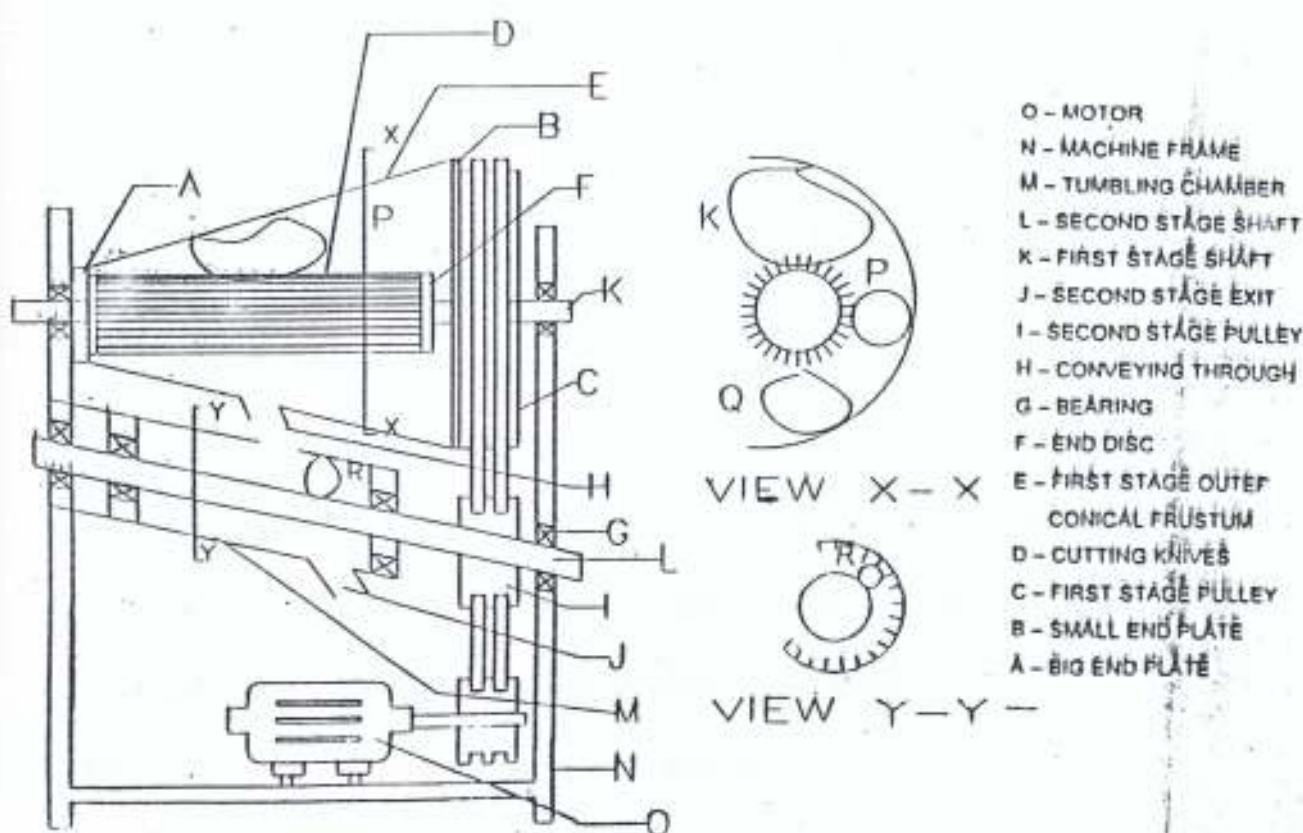


Figure 7: Improved Ohowovoriole's Rotary peeling machine
Source: Ariavie & Ohowovoriole, 2002

2.8.1.7 Design and construction of a manually operated cassava peeling machine

Itodo (1999) designed and constructed a manually operated cassava (*Manihot esculenta* Crantz) peeling machine. The machine has a peeling unit, a discharge outlet, and a handle that serves to transmit manual power to the peeling unit. The computed power required for operating the machine was 0.3 to 0.6 horse power. The peeling unit consists of brushes arranged on the circumference of a rotating drum and brushes arranged on springs on the inside of concave to facilitate the peeling of irregular shaped roots. The cassava roots are peeled by the scrubbing action of the brushes on the concave and the rotating drum when roots are introduced into the space between them. Unpeeled roots were put into the machine through the hopper and come out peeled from the discharge outlet. Figure 8 shows the peeling machine with details of the plan, sectional and side views.

A performance evaluation of the machine showed that the machine has a peeling rate of 97kg/h which is an improvement over the experimentally determined manual rate of 48kg/h per person. The machine was capable of removing 42% of the periderm and cortex of the roots at 74% moisture content. The advantage of this machine is that it has a higher peeling rate than the manual method. The disadvantages are that there is no provision for separating the peeled material from the peeled roots, and that the roots must be cut into short

and small units implying higher labour. He also recommended that the fibrous brushes used for peeling on the machine be replaced with metal brushes to ensure the complete removal of the root cortex, and thereby prevent cyanide poisoning when roots are processed and consumed as food.

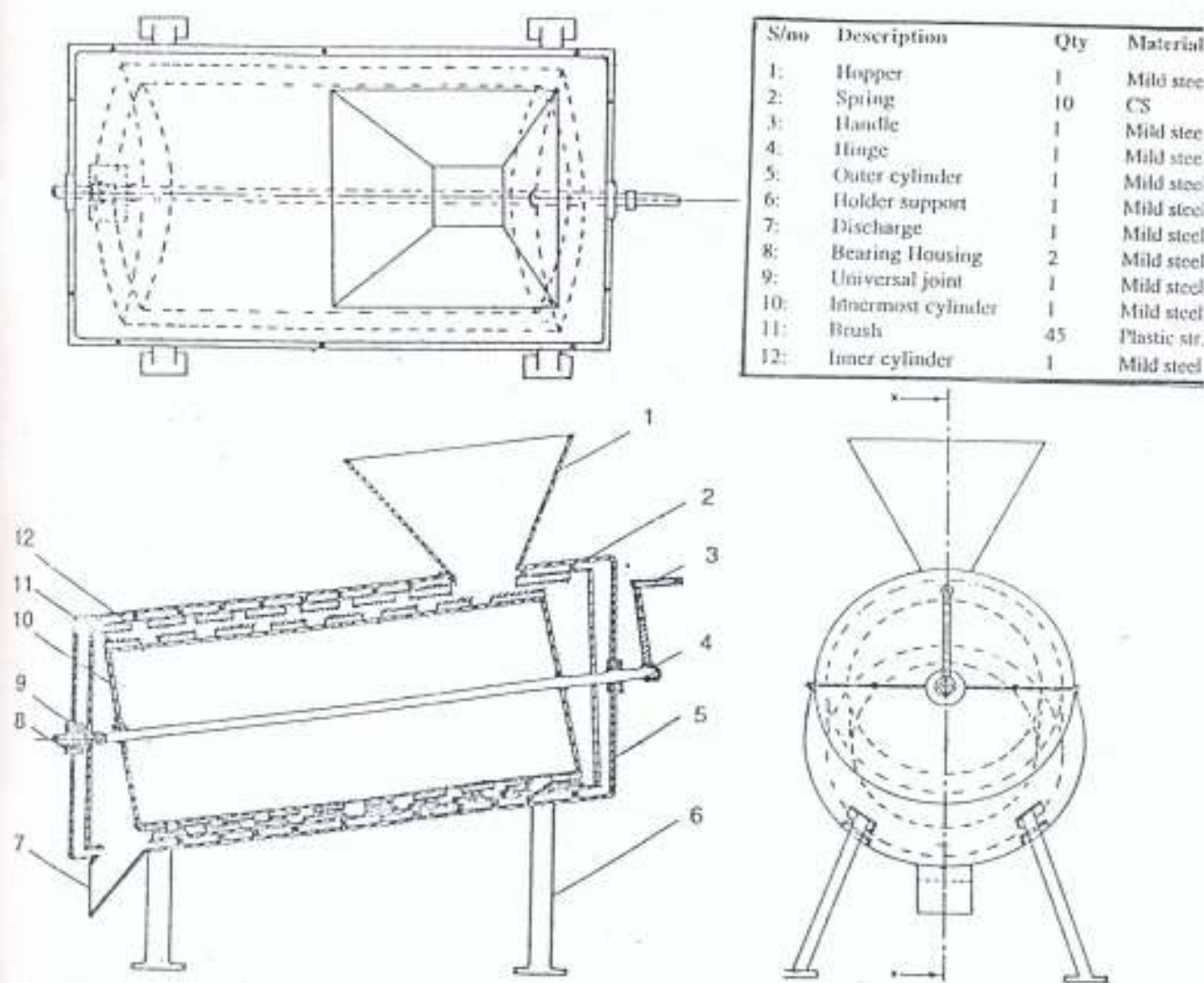


Figure 8: Manually operated cassava peeling machine
Source: Itodo, 1999

2.8.1.8 FUTA Cassava peeling machines (Single and double gang)

Models A&B

Two models of cassava peeling machines (Single and Double gang) have been developed at the Federal University of Technology, Akure, Nigeria. The machine as shown in Figure 9 consists of an abrasive brush, 120mm diameter, 150mm long mounted on a 25mm shaft. It receives motion from a 5 horse power engine rotating at 200rpm to 300pm. A protective hood to prevent splashing of dust and peels on the operator was provided. The hood also serves as a guide to direct the peel into the delivery chute. The drive system consists of belt and pulley arrangement with a speed ratio of 1:1 between the drive and the driven pulley. However, variation in speed was done by throttling the engine. The machine was demonstrated publicly at six different exhibitions. Various varieties of cassava which thrive well on Nigerian soils were identified and used for the performance evaluation of the machine. The tuber was easily manoeuvred round the peeling brush by the operator and thus makes the machine able to peel varying shapes and sizes of cassava. The machine was produced locally and the spare parts are readily available. They are easy to operate and maintain. Necessary routine maintenance is similar to that of pepper grinding machine. Depending on the models, for example, Single gang cassava peeler is capable of peeling 2 tons of Cassava per day and consumes

about 8 litres of petrol (FUTA Extension Bulletin Series 1, 2004; Agbetoye et al., 2006).

2.8.1.9 FUTA Cassava Peeling Machine (Self-fed) Model C

An Improved design as shown in Figure 9 uses the abrasive brush in the previous design, but incorporates an auger as well as a guide to monitor tuber movement in the peeling chamber. A 7horsepower engine was chosen as the power source. The brush – auger arrangement impacts a rotary and linear motion on the tuber. The brush rotates faster at a range of 500rpm to 1500 rpm while the auger also rotates at 120rpm to 450 rpm. The brush and auger also rotates in opposite direction. The relative motion between the brush and the auger together with the rotary motion of the tuber effect the required peeling. The guide provided was spring-loaded in order to accommodate variation in tuber sizes and shapes. The effective operation of this machine was however, dependent on tuber trimming and cuttings in order to eliminate bends. The width of the peeling chamber is also adjustable. The latter enhances effective peeling of tubers with various sizes. The capacity of the improved design is 10 tons per day (Olukunle et al.,2005; Agbetoye et al., 2006).



Single Gang
Cassava Peeling Machine,
Model A



Double Gang Cassava Peeling
Machine, Model B



Self-Fed Cassava Peeling Machine (Sides A and B), Model C

Figure 9: FUTA cassava peeling machines (Models A-C)
Source: Olukunle et al. 2005, FUTA Extension Bulletin Series I, 2004

2.8.1.10 Abrasive belt conveyor for mechanical peeling of cassava and yam

Ezekwe (1976) tried to use an abrasive belt conveyor for peeling of cassava and yam. The roots are first cut into slices before being introduced into the machine. The system consists of a conveyor which carries blade and moves the slices over a horizontal belt moving in a counter direction. As the slice rotates, a continuous slip occurs between it and the conveyor blade and pad, and leads to its subsequent peeling.

2.8.1.11 NCAM Improved Cassava peeling tool

Oni (2003) reported the development of a tool used for peeling cassava tubers. Its application is less tedious compared with the energy and time expended during the use of traditional tool such as kitchen knife. The main features of this tool are peeling blade and a handle which are made of mild steel. The output capacity of the peeling tool is about 35 kg/h and its peeling efficiency is as high 99% while tuber loss is less than 0.4%. The tool is ready for commercial release.

2.8.2 Yam peelers

2.8.2.1 Design construction and performance evaluation of an industrial yam peeling and slicing machine

Ukatu (1994) design, construct and evaluate the performance of an industrial yam peeling and slicing machine. The machine consists of a tuber container, a conveyor system, a peeling chamber, frames,

transmission and electric prime mover. The peeling unit of the machine consists of a conveyor system, which accepts unpeeled tubers, and delivers them to where they would be peeled and a peeling chamber where peeling takes place. A slope connects the peeling unit to the slicing unit. This slope allows peeled tubers to slide into the slicing unit. The slicing unit meters the peeled tubers to the slice blades area where slicing takes place.

The machine was designed and constructed for continuous peeling and slicing. The peeling unit was designed to handle tuber diameter of between 5 and 10cm. This range could be widened simply by replacing the peeling chamber with a large one. Many parts are spring-loaded to accommodate various size and shapes of yam. The slicing unit can handle any size of tuber. It can cut two different shapes, namely round shape and rectangular shape and both may be used for drying purpose and the rectangular shape for frying. Thickness of slices can be varied according to user's requirement.

From the results of the performance evaluation tests, the peeling efficiency varied from 60 to 80%. Operational speeds of 65rpm for the peeling chamber and 45rpm for the slicing unit were found to be most suitable. For peeling, the rate of work is 1.6cm/s but for slicing, the rate of work depends on the thickness of cut as it takes more time to cut into smaller slices for the same length of tuber. Each revolution of the slicer

blade makes a cut. Material recovery ranged between 82.7% and 88.8%.

2.8.2.2 Development of an Industrial yam peeler

Ukatu (2002) developed an industrial yam peeler for white yam (*Discorea rotundata*). The mechanical yam peeling machine which peels by abrasive action was developed and tested. The machine is shown in Figure 10. It makes use of blades arranged to traverse round tubers to perform the peeling action. The blades can be adjusted to vary the depth of peeling. The major parts of the machine are:

- (i) a tuber container;
- (ii) a conveyor system to convey tuber to where they will be peeled and withdraw them after peeling;
- (iii) tuber guides which ensure that any incoming tuber is directed right to the peeler blades;
- (iv) peeling chamber where peeling takes place.

Peeling efficiencies ranged from 60 to 80%. Higher peeling efficiencies were obtained for the tubers that are fairly straight than those that tend to be curved. Material recovery was from 82.7 to 88.8% where the mass of peel was treated as lost material also. The functioning of the machine is independent of tuber mass, moisture content and diameter. It peels yam tuber at an average rate of 16mm/sec irrespective of tuber size and moisture content.

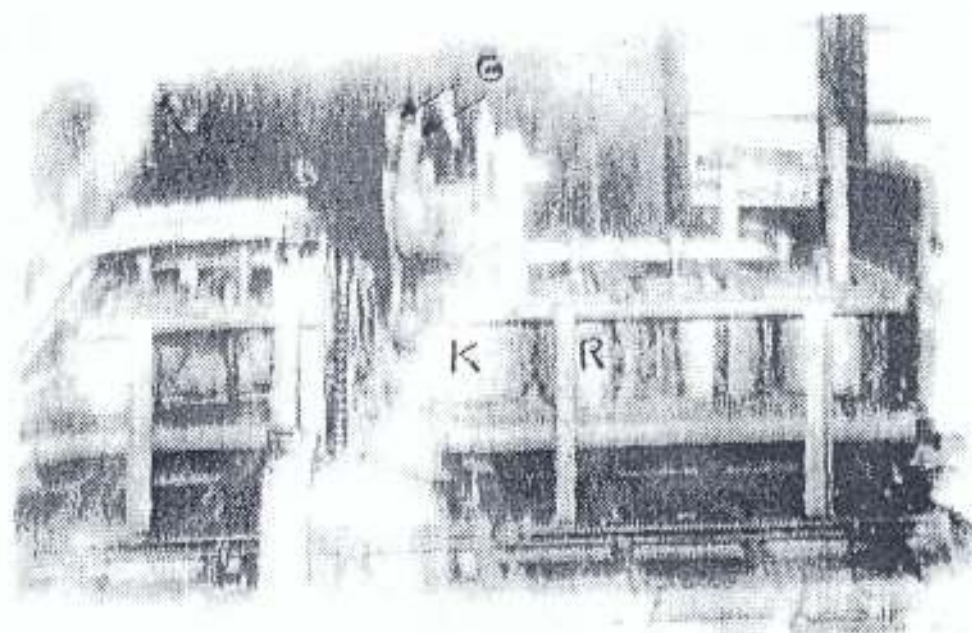


Figure 10: Development of an Industrial yam peeler
Source: Ukatu, 2002

2.8.3 Ginger Peelers

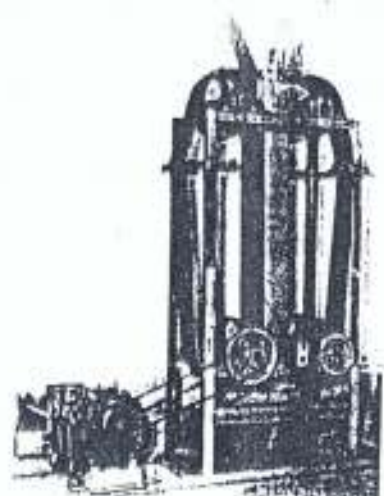
2.8.3.1 Development of an abrasive brush type ginger-peeling machine

An abrasive type ginger-peeling machine was designed and developed by Agrawal et al. (1983) because of the following reasons:

- (a) Abrasive peelers are simple in construction, compact, have low installation cost and are convenient to operate;
- (b) Abrasive peelers are safe to operate as they do not use any chemical for peeling; and

(c) Little extra equipment such as washers are required with abrasive peelers.

The machine as shown in Figure 11 consists of two endless canvass belts mounted on flat pulleys moving in opposite directions with a relative velocity of 1990mm/s downward. The belts have steel wire brushes on their outer surface and are driven by a power transmission system consisting of 1 horse power motor (single phase).



1 Abrasive brush type ginger peeling machine

Figure 11: Development of an abrasive brush type peeling machine
Source: Agrawal et al. 1987

3.3.2 Modification of brush type ginger peeling machine

Khandewal and Sharma (1982) latter modified the abrasive brush type ginger-peeling machine developed by Agrawal et al.1983. It was

however; felt that this machine may not be suitable for small farmers for two reasons;

- (a) The cost of the machine would be approximately 20,000 Rupees (including motor) which is beyond the reach of small farmers in India; and
- (b) The machine consists of specially cast pulleys and specially built brush belts lending it suitable for commercial manufacturing only.

2.8.3.3 Development and performance evaluation of an abrasive brush type ginger peeling machines

The abrasive brush type ginger peeling machine as shown in Figure 11 essentially consisted of two continuous brush belts being driven in opposite directions with a downward relative velocity by a variable speed motor. The movement of the two brush belts in opposite directions provided the abrasive action on the ginger passing in between, while the downward relative velocity provided the downward flow of ginger (Agrawal et al.1983). The spacing between the belts and the belts velocity could be varied. The machine was reported to functionally operate satisfactorily during the limited tests performed on stored ginger. Operational parameters of the abrasive brush type ginger peeling machine were evaluated and established for maximum efficiency with minimum ginger meat loss. The capacity of the machine operated at the recommended machine parameters was determined.

28.3.4 Development of a low cost manually operated ginger peeling machine

A low cost manually operated ginger peeling machine as shown in Figure 12 was developed by Radha (1995) to suit small farmers. The machine can be built and repaired by local artisans using locally available materials. One of the abrasive surface was kept stationary with sufficient inclination to facilitate downward movement of ginger. Manual drive was given to the machine in order to minimize its cost. Brushes made of coconut fibers were used in moving as well as on stationary abrasive surfaces. The hardness of coconut fiber results in better abrasive action while flexibility helps in cleaning the grooves or irregular surface of epidemic layer. The machine gives 71% peeling efficiency with 1.3% material loss in its full capacity operation of 24Kg/h in 5 passes for fresh ginger. With pre-treated ginger in lye solution, it gives 83% peeling efficiency and 2% material loss.



Figure 12: Development of a low cost manually operated ginger peeling machine

Source: Radha, 1995

2.8.3.5 Development of ginger root peeling machine

Aniyi (2000) developed an abrasive brush type ginger peeling machine. The machine essentially consists of two continuous brush belts being driven in opposite directions with a downward relative velocity of a variable speed motor. The movement of the two brush belts in opposite direction provides the abrasive action on the ginger passing in between, while the downward relative velocity provides the downward flow of ginger. The spacing between the belt and the belt velocity could be varied. The machine, after testing was found to have an efficiency of 85% with 2.5% material loss. The experimental machine has a throughput of 200 Kg/h. The sectional view of the ginger root peeling machine is shown in Figure 13

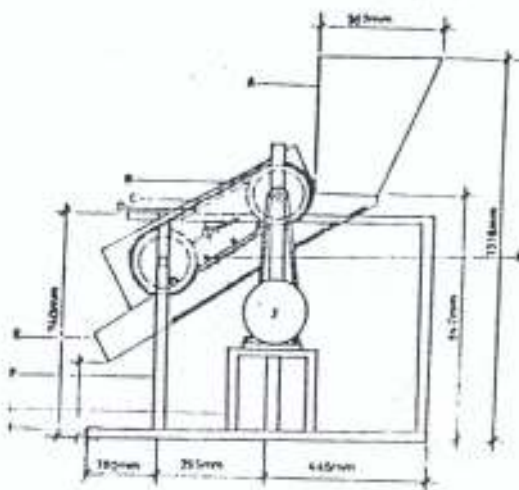


Figure 13: Development of ginger root peeling machine
Source: Aniyi, 2000

2.8.4 Potato Peelers

Potatoes are peeled by the use of heat, chemical and abrasive action. Types of peelers that have been used to peel potatoes include abrasive, lye, steam, brine and flame peelers (Ukatu, 1994). The batch type of peelers had earlier on been discussed under sub section (2.7.1).

2.8.4.1 Continuous abrasive peelers

They vary in design but basically have the same elements found in the simple design of the batch type peeler. The primary objective of all abrasive peeler is to ensure the spinning or rotation of the potatoes being peeled so that all surfaces are equally exposed to the rasping action of abrasive surface (Ukatu,1994). Water sprays flush potato tissues from the abrasive surfaces and reduce the tendency of potatoes to darken through enzymatic action. How well this objective is achieved determines the effectiveness of the equipment under given set of conditions. Shape and volume of potatoes greatly affect its efficiency. Round potatoes are much more suitable for abrasive peeling than long types. Overloading abrasion peelers interferes with the normal path that the potatoes travels and results in less efficient peeling and greater peeling losses (Ukatu, 1994).

Non-uniformity in size has been observed to cause uneven peeling with abrasive peelers. Varieties having deeper set of eyes are not suitable for abrasive peeling since additional trimming is required to remove the eyes remaining after peeling. The surfaces of the abrasive

rolls in continuous peelers may vary in roughness. Rolls with finer abrasive surfaces are placed near the discharge end of the peeler in order to obtain a smoother surface on the peeled potatoes (Ukatu, 1994).

Although marked improvement has been achieved in the development of abrasive peelers during the past few years, none has proved to be entirely satisfactory for all potatoes (Talbert and Smith, 1975). Eye and stem removal still remains a problem with certain types of potatoes. Creig (1956) reported the advantages of abrasion peelers to be their simplicity of operation, compactness of the unit, low cost of installation, and convenience of operation. The surfaces of potatoes peeled by abrasive peelers have not been altered by contact with high temperature. Peeling losses are usually higher with the abrasive method than with steam or lye peeling.

2.8.4.2 Development of a batch wise operating potato peeler prototype

Sourtti and Malkki (1980) developed a batch wise operating potato peeler prototype. Experiment to prepare boiled deep-frozen potatoes to be used as a component in deep frozen dishes was performed. A favourable quality was obtained from fully matured potatoes by cooking and freezing the potatoes while unpeeled. The peeling was performed in the frozen state by thawing the outermost layer and rubbing this soft layer away. For peeling, a batch wise operating prototype with a capacity of 50kg/h has been developed. The

peeler has three vertical rollers, fitted with a rubber studs, parallel to each other and in a V- shaped position. The speed of the rollers has a constant direction of running. The potatoes are fed between the rollers. In the first stage, the upper rollers are run upwards from the centre of the peeler, thus the potatoes are jumping and all parts of them touch the scrubbing studs of the rollers. In the second step, the direction is changed in order to scrub off carefully all thawed piece as well as to remove the remaining eyes and other harder points.

After peeling, a visual control is necessary for re -circulating the incompletely peeled tubers and for removing the defectives. The peeling can be done at the beginning of, during or at the end of the frozen storage without any effects on the quality. The losses in the peeling method are small. For potatoes with a diameter of about 60mm, the losses are 10-20% and with a diameter of 30-40mm, the losses are less than 30%. The peeler for frozen boiled potatoes is shown in Figure 14.

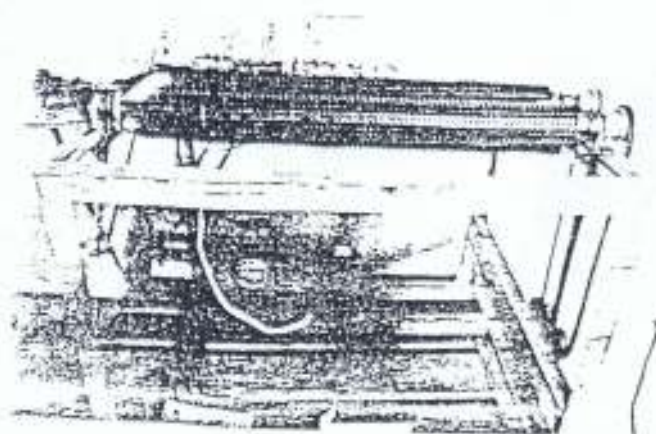


Figure 14: Development of a batch wise operating potato peeler prototype
Source: Sourtti & Malkki, 1980

2.8.5 **Essential Oil Removal from Orange fruits**

A machine for removing essential oil from orange fruits so as to eliminate manual peeling during processing has been designed, a model of it was fabricated and installed in the Medium Scale fruit juice processing factory at the Federal University of Technology, Akure (Agbetoye and Adesina, 2003). The picture of the machine is shown in Figure 15. The major components of the machine are the vibrating trays, frame, suspension springs, out- of- balance weights, water tank, water pumps, pipes, belt and pulley drive system and the electric motor to drive the machine. The preliminary results indicated satisfactory performance (Ogunlowo et al., 2005; Agbetoye et al., 2006).

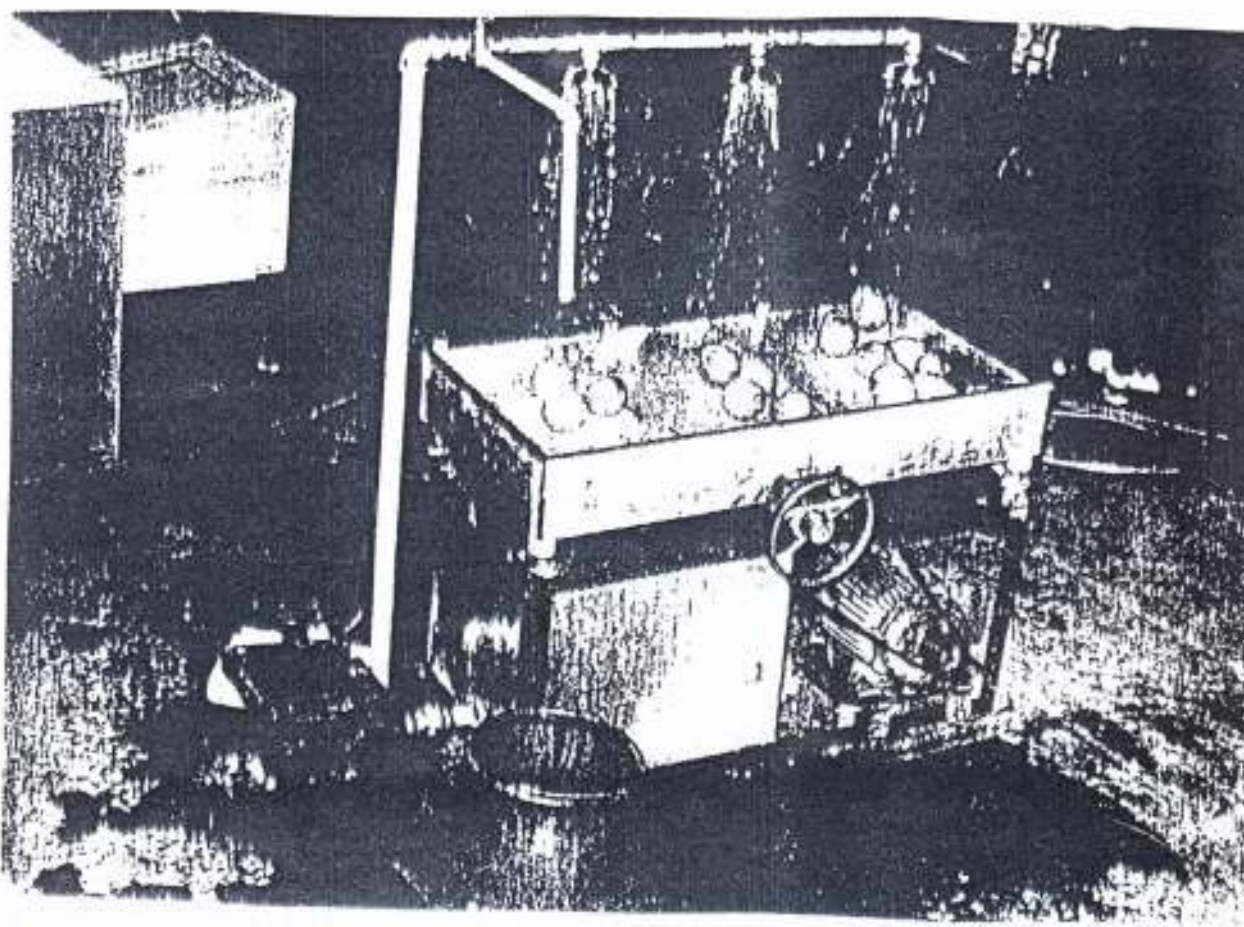


Figure 15: Essential oil removal from orange fruits
Source: Agbetoye and Adesina, 2003; Ogunlowo et al. 2005; Agbetoye et al, 2006

2.9 INDUSTRIAL PEELING MACHINES

In recent times, peeling machines have been manufactured in the developed countries like the United States of America, United Kingdom, Japan, France, Brazil, and so on. Also many agricultural manufacturing companies in these countries have several methods for removing the outer skins from root and tubers, vegetable and some fruits. Industrial peelers have also been developed for some agricultural crops. For example, fruit such as apples and pineapples are peeled by cutters, the former in a peeling and coring machine and the latter in a coring and sizing machine (Slade, 1967)

Many of these overseas peelers are unsuitable for local use in Nigeria, because they are very expensive, requiring large sums of hard currency to buy and maintain. They are also economically unsuitable to most small and medium scale fruit processing factories in Nigeria.

A survey of some of these manufactured industrial peelers is reported below.

2.9.1 International Potato Centre (CIP) Motorized Peeler

A sheet metal cylinder or 55 gallon drum whose surface has been punched from the outside to create an abrasive surface internally is mounted on a horizontal axle. The drum is rotated via a belt-drive from a motor. Potatoes are fed into the drum from the top, and as the cylinder rotates, the protruding holes scrape the skin from the surface of the potatoes. Each end of the cylinder is fitted with a small door so that

the potatoes may enter at one end and leave from the other when peeling is complete. A perforated metal pipe set above the cylinder sprays water over the rotating drum. 20 kg of potatoes can be peeled in 4 minutes. Final trimming and peeling is necessary (UNIFEM/IT, 1989). Figure 16 illustrate the CIP motorized peeler.

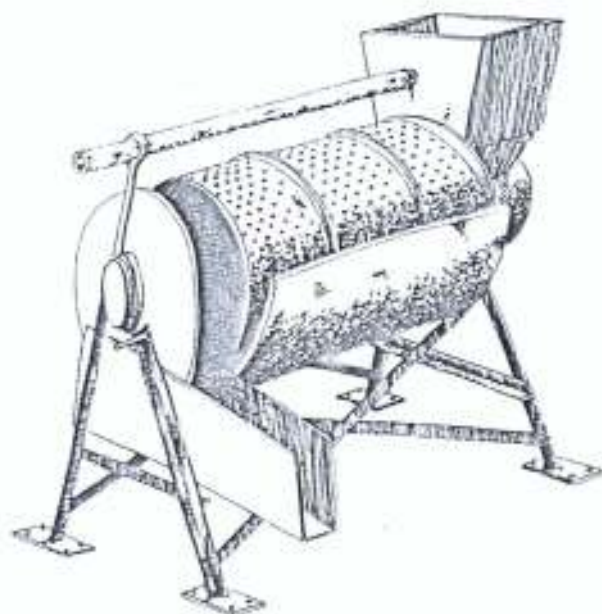


Figure 16: International potato centre (ICP) Motorized peeler
Source:UNIFEM /IT, 1989

2.9.2 Abrasive Plate Peeler

The 'Crypto peerless' abrasive plate peeler is an example of a typical commercial machine in which a rotating abrasive plate rubs the

skin from the material passed through. It is most commonly used to peel potatoes. Various sizes of such machines are available from as small as 13 kg per batch. They are powered by electric motor (UNIFEM/IT, 1989).

2.9.3 Lye Peeler for Root Crops

Hot solutions of sodium hydroxide (lye) can be used to loosen skin of many root crops to facilitate later peeling, such as removal by water spray or scrubbing with brushes. A combination of chemical reaction and thermal shock aid in softening and loosening the skin. The desired effect can be obtained by selecting the combination of lye concentration, temperature and immersion time. Generally, Lye acts more vigorously at higher temperature. Technical advice should be sought, if peeling is being considered, as problems can occur. For example, partial cooking and gelatinization of the outer layers of the root may, caused too much lye absorption. In addition, sodium hydroxide is a very dangerous chemical to handle and workers need to be properly trained and protected. In addition, the use of lye solution is a potential source of pollution and can corrode equipment (UNIFEM/IT, 1989). Figure 17 illustrate the lye equipment for peeling root crops.

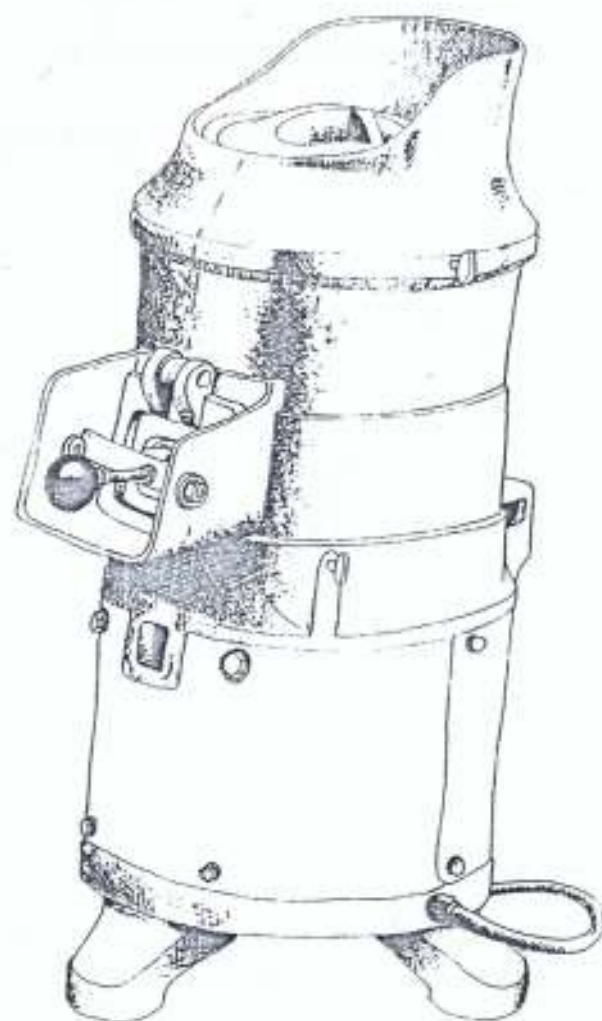


Figure 17: Lye peeler for root crops
Source: UNIFEM/IT, 1989

2.9.4 Pineapple Sizer and Corer

Pineapples can be peeled and cored in the following way. The pineapple is trimmed at both ends and placed into a V-shaped spring loaded trough as the operator centers the coring tube. The pineapple is held with the left hand and the manual lever is moved until the coring tube has pierced the fruit. The foot pedal is depressed which raises the stop bar holding the fruit in a coring position. It has a throughput of 600-

720 operations per hour (Small Scale Food Processing, 2000). The pineapple sizer and corer is shown Figure 18.

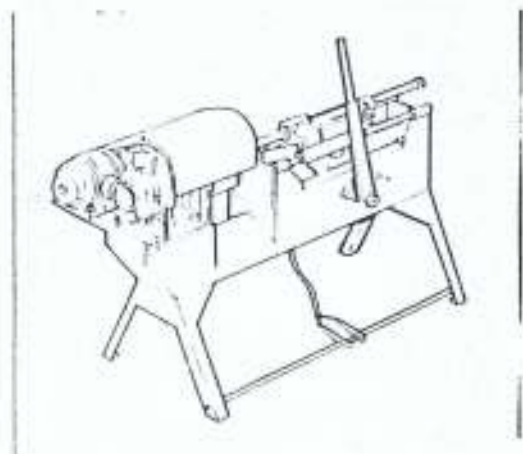


Figure 18: Pineapple sizer and corer
Source: Small scale food processing, 2000

2.9.5 Fruit Peeler

Fruit is positioned on a central pivot. As the handle is turned, the fruit is revolved over a stationary knife and the peel is removed (Small Scale Food Processing, 2000).

2.9.6 Best Apple Parer (Peeler)

This small, sturdy apple peeler is hand operated. The apple is removed at the end of each cycle. The tool is fabricated from cast iron with a nickel plated apple spike and a replaceable steel blade. The unit will clamp onto surfaces up to 3.2 cm thick. It has a throughput of 360

apples per hour (Small Scale Food Processing 2000). Figure 19 illustrate the best apple parer (peeler).

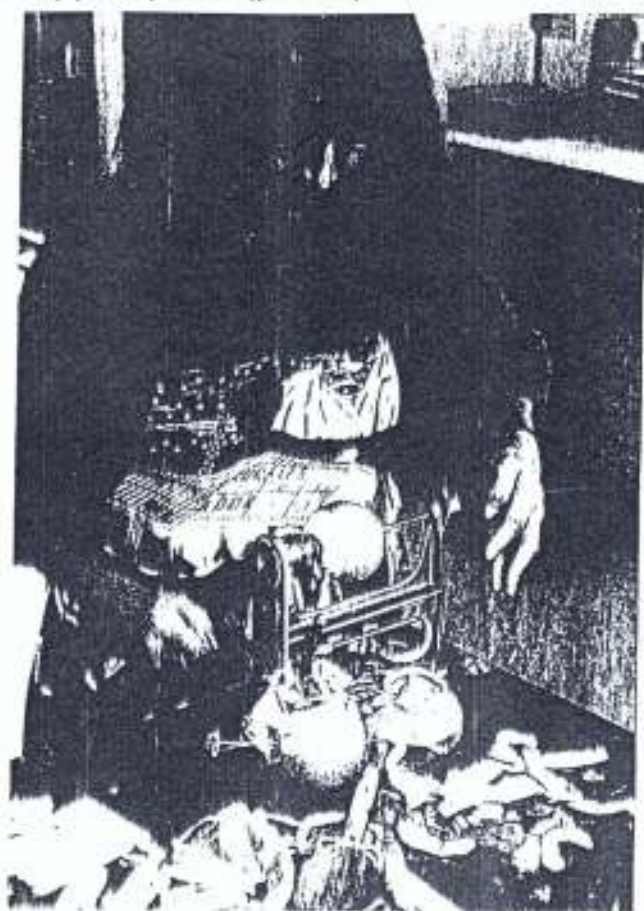


Figure 19: Best Apple parer (Peeler)
Source: Small scale food processing, 2000

2.9.7 Lye- Type Peeler Scalders

This machine loosens the skin of root crops and some fruits. The unit is made from galvanized material and is equipped with a steam heating coil, quick opening drain, rinsing compartment, and rinse basket. The basket containing the product is placed in the lye peeling section. It is then transferred to the rinsing compartment after a few minutes (the actual time depends on the product being peeled) (Small Scale Food Processing, 2000).

2.9.8 Electric Potato Peeler

This stainless steel, bench top potato peeler has a motor and a V-belt which drives a spindle inside a container. The potatoes are rotated against the abrasive walls. There is a hose entry for cleaning water and an exit for potato peeling (Small Scale Food Processing, 2000).

2.9.9 Root Crop Peeler/ Washer

This machine has a peeling drum with a carborundum, drum surface to peel the food. A water spray continuously removes loosened peel from the machine. Processing is done in batches of 15-20kg. It has a throughput of 100kg per hour of peeled roots (Small Scale Food Processing, 2000).

3.0 THE GENEVA (WHEEL) MECHANISM

The Geneva wheel, commonly called Maltese cross, is a cam like mechanism with an arbitrary number of slots (the minimum being three and the maximum eighteen) and has a substantial dwell during a portion of its operating period (Shighley and Uicker, 1980).

A Geneva wheel converts uniform rotary motion into intermittent rotary motion. A pin in a driving wheel engages a slot in a driven wheel, rotates the slot (and driven wheel) through some arc, and then moves out of engagement. Thus for each complete revolution of the driving

wheel, the driven wheel moves through a partial revolution and then remains stationary until the pin engages another slot (ICATVT Mechanical Drives Manual, 1984). Driven wheels typically have from 3 to 18 slots. The driven wheel is normally held stationary (while the pin is not in engagement) by a locking ring which conforms to the contour between slot arms (ICATVT Mechanical drives Manual, 1984) as shown in Figure 20.

Operating characteristics such as acceleration, velocity and displacement are determined largely by the number of slots in the wheel. The drives can be used in both light and heavily loaded applications including some at very high speed, in counting machines / instruments, in automatic machinery as well as in motion- picture projectors to provide the intermittent advance of the film through the intermittent rotary motion that it provide when driven by a link of a mechanism (Beer and Johnston, 1972; Mabie and Ocvirk, 1978 and ICATVT Mechanical Drives Manual, 1984). The intermittent rotary motion of the Geneva wheel coupled with its idle (dwell) period is of interest since these dwell periods, in between motion of the wheel, can find ready application in a good number of industries in Nigeria (Akpaidu and Dahunsi, 1999).

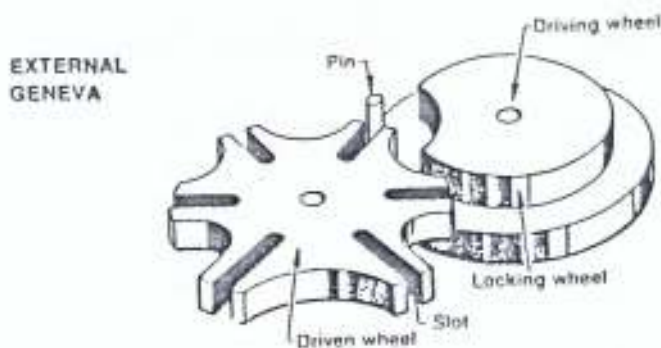


Figure 20: External Geneva mechanism

Source: ICATVAT Mechanical drives manual, 1984; Akpaidu & Dahunsi, 1999

3.0.1 Industrial applications of the intermittent motion of the Geneva mechanism in Nigeria

Geneva mechanism has found several industrial applications today due to various designs and adaptations based on the principles of mechanisms. A number of some of these applications had previously been mentioned in sub section 3.0. Apart from these areas of applications, the use of the intermittent motion of Geneva mechanism with its associated dwell periods in such areas as material handling, quality inspection and components assembly should be seriously considered in our engineering outfits involved in manufacturing and processing activities where conveying systems are employed (Akpaidu and Dahunsi, 1997).

Material handling has metamorphosized from the use of ordinary hands to the use of conveying system, some of which are mechanical, semi-automatic and automatic handling equipment. The conveyance of

materials using a conveyor belt or chain on sprockets incorporating a Geneva mechanism is an area of concern. For a horizontal layout, such a system has a relatively fixed route and where it is employed in continuous manufacturing processes, the materials leaving a work station could invariably go to some other specific work station where removal or addition of material is effected more efficiently on the production line during the dwell period (Akpaide and Dahunsi, 1999).

The case of components assembly is quite similar to that described above. With the dwell periods, the craftsman at each work station is given a more time to carry out sub-assembly operations instead of moving along with the job if the conveying system is the continuous motion type. A better attention to the unfinished product is also guaranteed during the dwell period of the motion. It also allows for the use of this intermittent motion with the inherent dwell periods during the quality inspection of washed bottles and the level of liquid contents of the products of our bottling companies. The present situation is that the operations are stationed at strategic locations to either remove unwashed bottles under a screen light or to remove bottles whose liquid content is not to specification. The effectiveness of their operation or quality inspection can be improved upon by using the derived motion with the dwell (stationary or idle) period of the Geneva mechanism. If longer dwell period is required, the use of long dwell Geneva can be introduced (Chironis 1965).

3.0.2 Application of the intermittent motion of the Geneva (wheel) mechanism to indigenous machine development in Nigeria

The Geneva mechanism has found several applications in the development of indigenous machines where it becomes necessary to convert continuous motion to intermittent motion. A review of the available literature reveals that this mechanism has been used for successful development of some indigenous machines in the department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. Notably among the machines developed are:

3.0.2.1 Development of Large-Scale Water Hyacinth Harvester

A large scale water hyacinth harvester was developed by Ademosun (1991) and Ademosun et al., (2003). The major components of the machine are the intake rollers, intake reel, vertical mowers, chopper, loading conveyor, transverse conveyor, weed pusher, storage conveyor and discharge conveyor. The machine is rugged and sturdy. The machine applies the intermittent motion of the Geneva mechanism to harvest sea weeds efficiently. Design specifications of the mechanism were based on a 5-slot Geneva wheel and some carefully chosen design consideration. The machine as shown in Figure 21 was designed to have a width of cut of 1.0metre so that at a forward speed of 10 knots, the estimated capacity of the machine is $18,500\text{m}^2/\text{h}$. The estimated weight of the harvester when full of weeds is 50 metric tons.

The machine was installed on a full size model barge and operated. There have been many public demonstrations of the machine. All the component parts of the machine performed efficiently well during both harvesting and off- flooding (Ademosun, 1991).

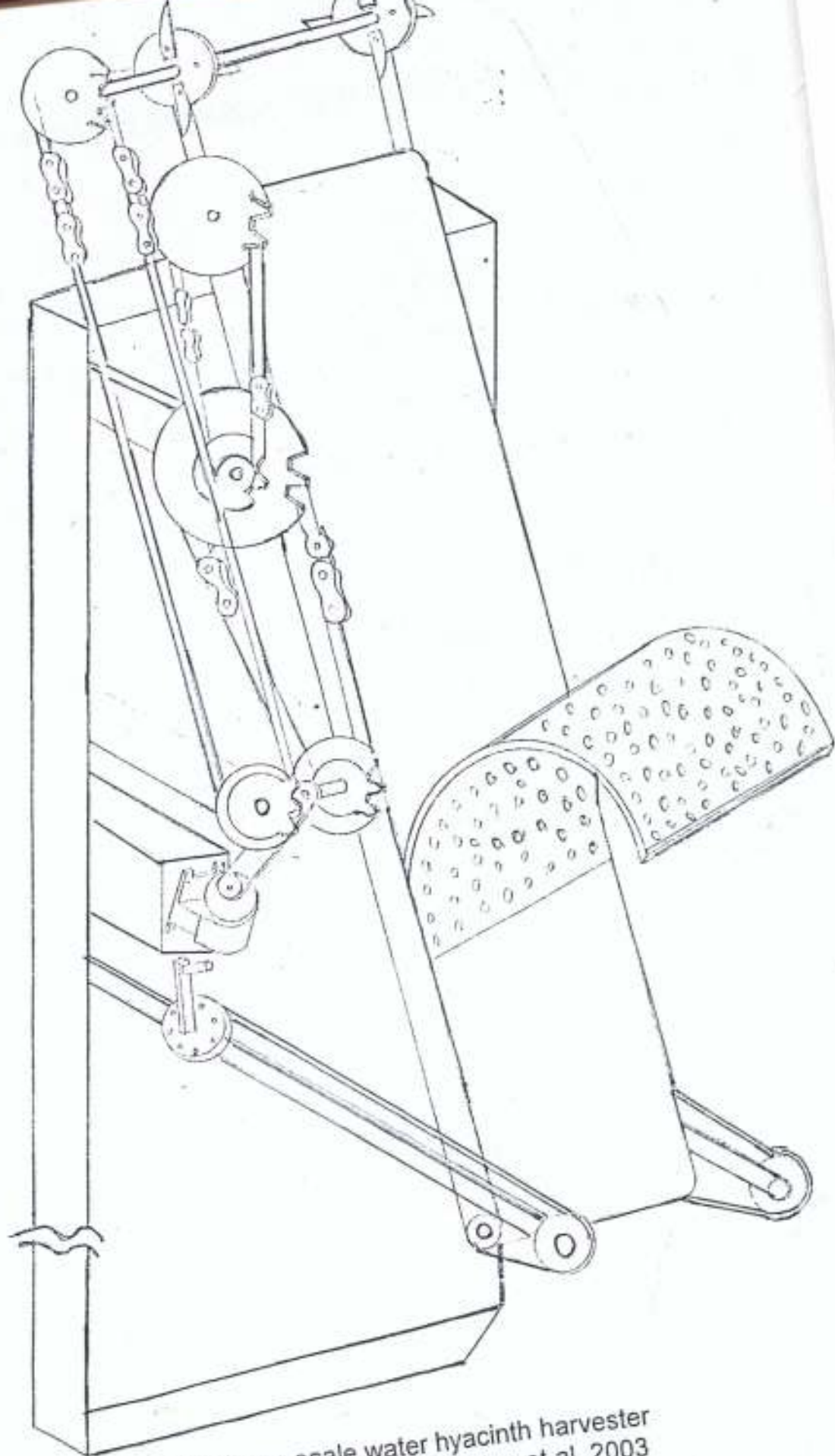


Figure 21: A large scale water hyacinth harvester
Source: Ademosun, 1991; Ademosun et al. 2003

2.2 Design, Construction and Evaluation of a Fruit Juice Bottling Machine

Ashaolu (2001) designed, fabricated and tested a fruit juice bottling Machine. The machine applies the intermittent rotary motion of Geneva mechanism to fill sequentially 50cl bottles with fruit juice. Design specifications of the mechanism were based on a 4- slot Geneva wheel and some carefully chosen design considerations. The machine conveys bottle at a speed of 0.125rev/s to fill a bottle. The speed of the pinwheel and Geneva wheel were 0.653rad/s and 1.574rad/s respectively. Pulleys and belt to transmit the calculated speed were selected. Suitable materials were also selected for the components of the machine. The machine as shown in Figure 22 was tested to have filling loss of 18.76% and efficiency of 86.12% with standard deviation of 7.58% and 2.16% respectively.

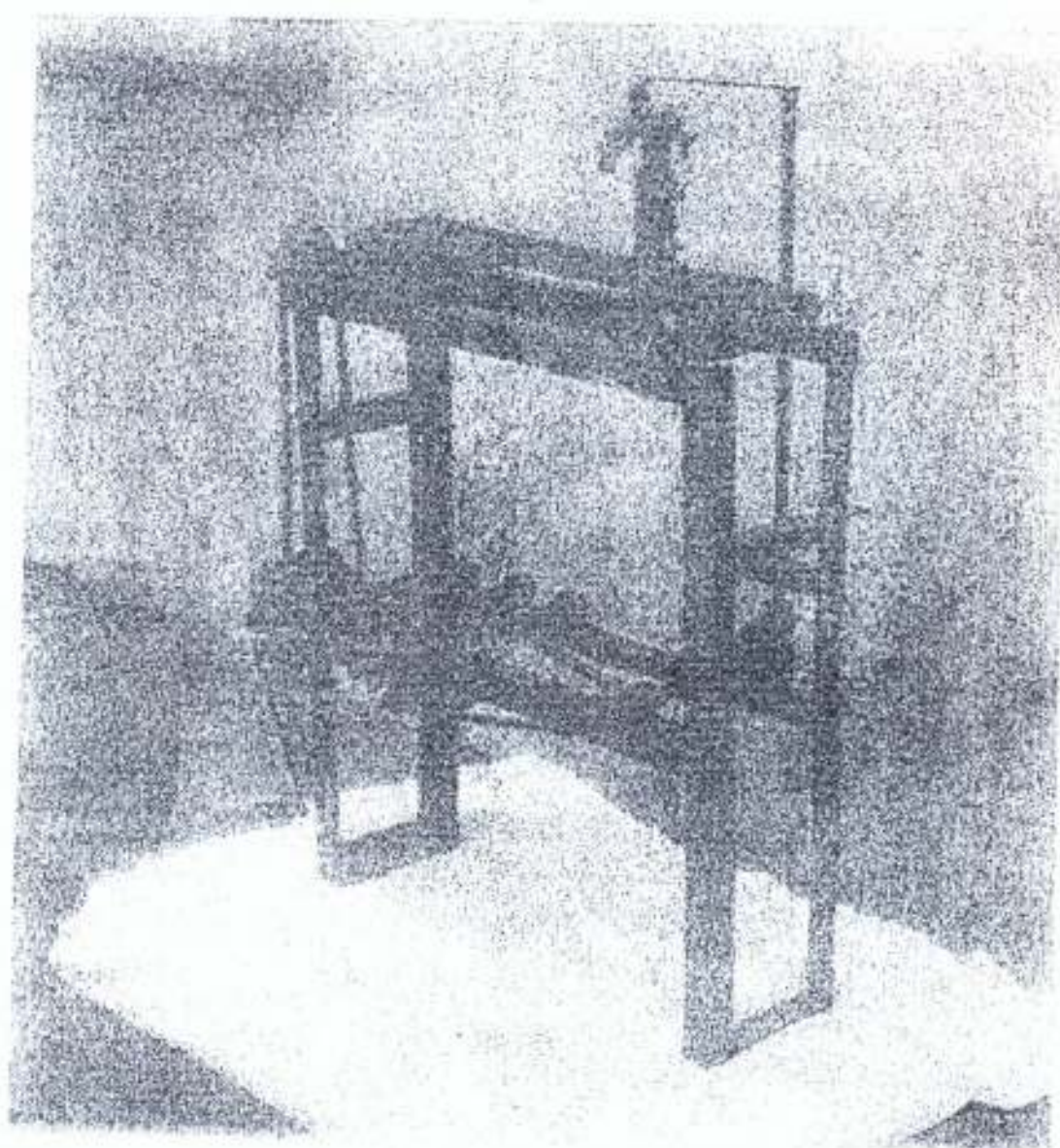


Figure 22: The Fruit juice bottling machine
Source: Ashaolu, 2001

CHAPTER THREE

MATERIALS AND METHODS



3.1 DESIGN CONSIDERATIONS

Before any system is developed, an abstract picture is first formed in the mind of researcher. This picture dictates both the design and functional requirements of the equipment. In the design of an orange peeler, the following requirements were taken into consideration:

1. The ability of the machine to peel oranges of different degrees of ripeness and sizes.
2. The design of the machine should accomplish complete and proper peeling of the orange outermost skin without causing any damage to the endocarp (edible portion).
3. The peeling should be done in reasonable time limit to minimize time loss in manual peeling.
4. Materials for fabricating the machine should be sourced locally in order to cut down the cost of the construction materials to be used.
5. The strength of the construction materials should withstand the forces acting in the various component parts of the machine.
6. The simplicity and flexibility of the machine should suit the targeted users. Also the cost of maintenance of the machine should not be too high.

7. The machine should require minimum number of labour for operation and should also relieve any fatigue during operation.
8. Some of the materials to be selected for machine fabrication should not contaminate the peeled orange. The peeling blade must not react with or contaminate the orange.
9. It was desirable that the power transmission system be efficient with minimized power loss. For this reason, belt and pulley drive systems, bevel gear, Geneva wheel and pin wheel were carefully designed according to prescribed standards

3.2 MEASUREMENT OF PHYSICAL DIMENSIONS OF SWEET ORANGE

Some physical dimensions of sweet oranges such as diameter of orange before and after peeling, peel thickness, length of peel and width of peel are required for the design of the machine. Measurements were conducted to determine those parameters for the sweet oranges. The orange diameter was measured first and later peeled with the aid of a sharp blade. Diameter measurements before and after peeling without bruising, were carried out by using vernier caliper. The peel thickness was measured with the aid of a micrometer screw gauge while the length of peel was measured by using a meter rule. Similarly, a meter rule was also used to measure the width of each peel. The total number of peels were counted per orange and also recorded.

Table 1 shows the data on the measurement of physical dimensions of oranges collected. The mean and the range of these measurements were also determined. The orange diameter before peeling ranged from 59.20 mm and 71.00 mm, orange diameter after peeling ranged from 55.40 mm and 67.30 mm, peel thickness ranged from 1.05 mm and 1.95 mm, length of peel ranged from 76.00 mm and 94.00 mm and width of peel ranged from 7.00 mm and 9.00 mm. These values were used as design data for example, in selecting the average dimension of the peeling chamber and also in the selection of appropriate thickness of the peeling blade.

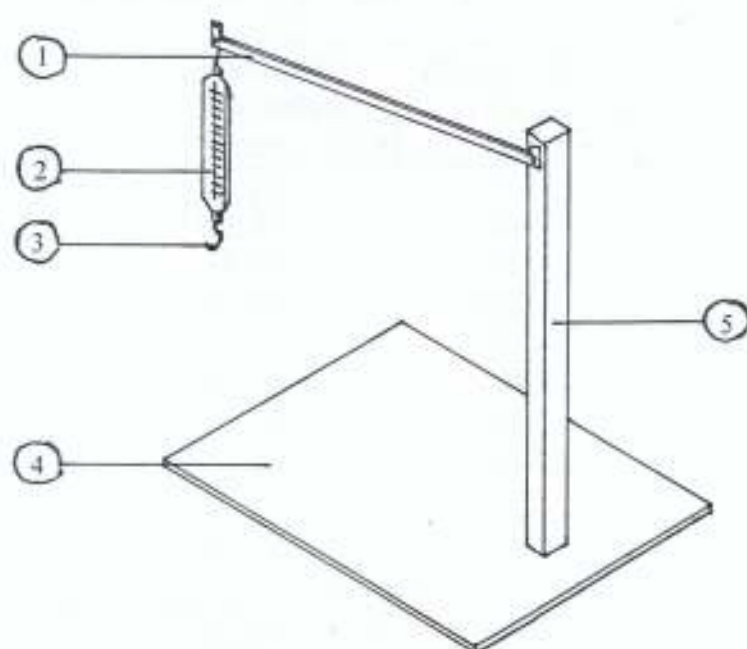
Table 1. Measurement of physical dimensions of Sweet Orange

S/no	Orange diameter before peeling, (mm) D	Peel thickness, t (mm)	Orange diameter after peeling (mm), d (d=D-2t)	Length of Peel, L (mm)	Width of Peel, w (mm)	Total Number of peels per orange
1	65.70	1.86	61.98	90.00	7.00	31
2	63.30	1.80	59.70	76.00	7.00	30
3	68.60	1.85	64.90	88.00	8.00	34
4	60.00	1.45	57.10	79.00	6.00	31
5	63.00	1.87	59.26	87.00	7.50	32
6	60.00	1.85	56.30	92.00	6.50	30
7	65.60	1.84	61.82	84.00	6.00	32
8	71.00	1.85	67.30	94.00	9.00	30
9	67.80	1.60	64.60	86.00	7.50	28
10	62.00	1.95	58.10	94.00	7.00	30
11	66.00	1.38	63.24	98.00	8.00	31
12	59.20	1.90	55.40	78.00	6.00	28
13	67.40	1.10	65.20	85.00	7.00	31
14	65.70	1.05	63.20	86.00	7.00	33
15	61.20	1.60	58.00	78.00	8.00	34
16	67.80	1.80	64.20	91.00	8.00	33
17	60.00	1.70	56.60	90.00	7.50	32
18	71.00	1.85	67.30	93.00	9.00	32
19	62.10	1.80	58.50	94.00	8.00	31
20	70.00	1.75	66.50	93.50	8.00	32
21	62.00	1.74	58.52	94.00	8.00	31
22	64.80	1.82	61.16	75.20	7.00	32
23	60.20	1.78	56.64	78.10	8.00	31
24	62.80	1.90	59.00	89.60	7.00	31
25	66.40	1.69	63.02	84.00	8.50	30
26	62.50	1.45	59.60	88.00	8.00	32
27	59.80	1.72	56.36	77.00	7.80	31
28	67.50	1.65	64.20	84.00	8.00	31
29	70.10	1.73	66.64	92.00	9.50	32
30	62.40	1.63	59.04	89.00	8.50	32
Total	1935.80	51.01	1833.38	2607.04	228.30	
Mean	64.52	1.70	61.11	86.91	7.61	
Range	59.20 and 71.00	1.05 and 1.95	55.40 and 67.30	76.00 and 94.00	7.00 and 9.00	

3.3. DETERMINATION OF THE EFFECT OF ORANGES OF DIFFERENT DEGREES OF RIPENESS ON THE PEELING FORCE

An experiment was carried out to determine the force required by a sharp blade to peel orange. Thirty (30) matured sweet oranges were obtained from the citrus processing division of the Joff Ideal Family Farms Limited at Owo in Ondo State. The oranges were selected and grouped into three categories of ten oranges each, taken into consideration their sizes and degrees of ripeness. In the experiment, a blade was attached through its hole to a spring balance (25 Newton maximum force). The spring balance with the blade and a hanging rod was further attached to a clamp on a stationary (standing) rod as shown in Figure 23. To determine the peeling force, the blade was positioned on the outermost skin of the orange and with the aid of a little force of the hand, the blade moves longitudinally on the orange outermost skin. The force produced as the blade moves longitudinally on the orange outer most skin was read on the graduated scale of the spring balance. This was done for oranges of different degrees of ripeness and sizes considered during the experiment.

The results obtained from the experiment was recorded and tabulated as shown in Table 2. It was observed that the peeling force varies for different degree of ripeness of oranges. The range of peeling force determined were 6.0 N and 7.5 N for green colour, 6.3 N and 7.5 N for pale yellow while 7.3 N and 7.5 N for yellow colour. A Knowledge of these peeling forces assisted in choosing the peeling blade of adequate strength.



S/no	Part s
1	HANGING ROD
2	SPRING BALANCE
3	BLADE POSITION
4	BASE PLATE
5	STANDING ROD

Figure 23: Peeling force determination equipment

Table 2. Determination of the effect of oranges of different degrees of ripeness on the peeling force

Ripeness of Orange	Diameter of unpeeled orange (mm)	Weight of unpeeled orange (g)	Average peeling force obtained (N)
Yellow	71.00	546	7.5
	67.80	540	7.4
	68.20	536	7.3
	67.90	520	7.3
	68.50	530	7.4
	65.20	456	7.5
	67.00	475	7.5
	68.30	425	7.5
	67.60	428	7.5
	66.90	398	7.4
Range of peeling force (N): 7.3 & 7.5			
Pale yellow	65.00	422	7.5
	60.00	451	6.5
	61.70	465	6.8
	61.20	400	6.5
	64.00	442	7.2
	66.40	465	7.2
	67.50	472	7.5
	62.50	402	7.0
	61.20	399	6.4
	59.80	397	6.3
Range of Peeling force (N): 6.3 & 7.5			
Green	64.50	400	6.0
	65.50	461	7.5
	62.50	399	7.0
	65.40	401	7.5
	66.80	464	6.5
	59.80	400	6.5
	60.10	402	6.4
	66.50	450	7.2
	59.70	400	7.0
	67.50	465	6.8
Range of Peeling force (N): 6.0 & 7.5			

3.4 DESIGN OF THE HELICAL SPRINGS

Helical Springs are usually made of circular cross-section wire or rod (Hall et al., 1980). This component was designed to provide support (underneath) for the orange placed in the peeling chamber. It was also to provide elastic deflections for various sizes of oranges placed for peeling. By following the procedure proposed by the Engineering guides on Helical Springs prepared by Spring Research Association (1974), U.K, two helical springs was designed and selected as reported in Appendix 1.

3.5 SELECTION OF BEARINGS

A bearing is a machine element which facilitates motion between a shaft and the fixed part or the part moving relative to the shaft. The radial load, axial load, equivalent load and the required life of bearing were taken into consideration during the selection. This component was selected to aid smooth transmission of motion between the following components: driven pulley and pinwheel, Geneva wheel and gear box, driven pulley and scotch yoke mechanism. By following the procedure proposed by PSG Tech., Design data (1982), three self aligning ball bearings was selected as reported in Appendix 2.

3.6 DESIGN OF THE BELT AND PULLEY TRANSMISSION

Belt design involves either the proper belt selection to transmit a required power or the determination of the power that may be

transmitted by a given flat belt or by one V-belt (Hall et al., 1980). By following the procedure proposed by PSG Tech., Design data (1982), a V-Belt was designed and selected as reported in Appendix 3 to transmit motion from the electric motor to the driven pulley.

3.7 DESIGN OF THE SHAFTS (DRIVING AND DRIVEN)

Design of two driving shafts to transmit power from the driven pulley to the pinwheel and then from the bevel gear to the peeling chamber was carried out together with a driven shaft to transmit power from the Geneva wheel to the bevel gear. All statics and dynamics stresses resulting from direct loading, bending and torsional stresses were also considered in both shafts design. By following the procedure enumerated by Hall et al., (1980) and by using the American Society of Mechanical Engineer (ASME) code for solid shafts having little or no axial loading as reported in Appendix 4 and 5, a 25mm diameter shaft was selected in each of the shafts design because it satisfies both the functional and strength requirements of the machine.

3.8 DESIGN OF THE CONNECTING ROD

This component was designed to hold the blade in proper position for peeling operation. Based on functional requirements, a rod of 405mm length and 10mm thickness was selected and welded to the

peeling blade. The design procedure and calculation is reported in Appendix 6.

3.9 DESIGN OF THE PEELING BLADE

This component was designed to impact the cutting action (longitudinally) by shear method on the orange outermost skin placed in the peeling chamber during operation. It was desired that the blade be strong enough to be able to peel at a thickness range of between 1.05mm to 1.95mm (as determined in Table 1). A mild steel of 1.5mm thickness which possess high corrosion resistance and also retains its sharpness for peeling at all times was selected. The design procedure for the blade selection is reported in Appendix 7.

3.10 DESIGN OF THE BEVEL GEAR

Based on functional requirements, this component was designed and selected because of the need to change the speed and power ratio of the driven shaft connected to the Geneva wheel to that required for peeling at the chamber. By following the procedure proposed by PSG Tech., Design data, (1982) as reported in Appendix 8, a bevel gear with a ratio of 7:1 was designed and selected to transmit motion at right angle to the vertical driving shaft holding the peeling chamber.

3.11 DESIGN OF THE SCOTCH YOKE MECHANISM

The mechanism consists of a yoke or rod, wheel and slider. This component was selected such that at any particular moment, the wheel of the scotch yoke through its pin transmits motion to the slider. Therefore, it was desired that as a result of the combination of the wheel and the slider during operation, vertical oscillatory motion will be transmitted through the yoke to the connecting rod. The parameters considered for the selection of this component is reported in Appendix 9.

3.12 DESIGN OF THE GENEVA MECHANISM

Based on the machine functional requirements, a six slots Geneva wheel was selected from the PSG Tech., Design data (1982). The Geneva mechanism consists of a pinwheel which also engages a slot in the Geneva wheel through some arc, and then moves out of engagement. This component was designed and selected as a result of the need to change the uniform rotary motion from the driving shaft linking the driven pulley to intermittent rotary motion. By following the procedure proposed by PSG Tech., Design data (1982), this component was designed as reported in Appendix 10.

3.13 DETERMINATION OF THE POWER REQUIREMENT

The ability of the machine to transfer power for slow speed drive was a major factor in the design of the machine. The speed requirement was determined to be 422.61rpm. Therefore, a 1kw electric motor delivery a turning speed of 1420 rpm was selected to drive the machine. The determination of the power requirement is reported in Appendix 11.

CHAPTER FOUR

PRODUCTION OF THE ORANGE PEELER

4.1 MATERIAL SELECTION FOR THE COMPONENTS

Every engineering material has its peculiar properties and its areas of application to suit a particular type of service. Choice of materials depend on many factors such as intensities and types of stress to which the components are to be subjected, whether it is to be flexible or rigid, whether it has to experience high temperature or corrosive actions and how it lends itself to process of manufacture. The machine to carry out such operations must attain some special characteristics. Also the physical, mechanical and chemical properties of the materials are very important for consideration.

The materials selected for each of the machine component or unit and reasons for selecting such material is presented in Table 3.

Table 3. Material selection for the components

s/no	Machine components	Criteria for selection	Most suitable material	Material actually selected	Reasons for selecting the material	Limitation of the material selected
1	Machine frame	Must be strong, very rigid, minimizes distortion, able to absorb impact shock	Angle iron	Angle Iron	High strength and rigidity, suitable enough to avoid buckling	
2	Helical spring	Very strong, compressible	Carbon steel	Medium carbon steel	Has high strength and rigidity	
3	Connecting rod	Bending resistance, strong, not too heavy	Mild steel	Mild steel	Readily available, very cheap and easy machinability	
4	Pulley	Resistance to wear, strong	Aluminum	Wood	Greater machinability and cheaper	Wears faster
5	Belt	Have elasticity to absorb shock without breaking	Leather	Impregnated rubber	Readily available, safe, adaptable, High allowable stress	
6	Driving and driven shafts	High wear resistance and strength	Carbon steel	Medium carbon steel	Possess high strength and rigidity, suitable enough to avoid buckling	
7	Bevel gear	Very efficient and rigid, strong during power transmission	Cast iron	Cast iron	Readily available and suitable for power transmission	
8	Peeling blade	Very strong	Stainless steel	Mild steel	Not corrosible and very strong	
9	Scotch yoke & wheel	Strong and not too heavy	Mild steel	Mild steel	Readily available and cheaper	
10	Geneva wheel and pin wheel	Strong and very rigid, able to absorb impact shock	Mild steel plate	Mild steel plate	Will not deflect during transmission	

4.2 FABRICATION OF THE MACHINE COMPONENTS

The machine was fabricated according to the design specifications. The main bought out components used for the machine fabrication included pillow block bearings, helical springs bevel gear and belt. The components fabricated included the frame, connecting rod, pulley, driven and driving shafts, peeling blade, Scotch yoke, Geneva wheel and pin wheel. The procedure below outlines the method taken during the fabrication of the machine components.

4.2.1 The machine frame

This unit bears the entire load of the machine. It is also the mounting support for all the components of the machine. The frame was made of 38mm x 38 mm angle iron. With the aid of steel rule and scribe, the correct measurements of the angle iron were marked out and cut to sizes using the hack saw. Also with the aid of try square and spirit level, the cut outs angle iron were arranged and set with 640 mm as length, 510 mm as breadth and 920 mm as height. These were welded together. While it is desirable to minimize the weight of the frame, it was sufficiently strong, rigid and high in order to avoid back straining of the operator. The frame for the electric motor base was also made from 38mm x 38mm angle iron with 110mm as length and 65mm as breadth. This was formerly held to the machine frame. A base with dimension of 640 mm x 510 mm was constructed with a 2mm thickness mild steel sheet metal.

This serves as cover on top of the frame and also prevents interference with the transmission unit.

4.2.2 Connecting rod

This was produced by cutting 450mm length from a mild steel rod of 20mm diameter. The cut rod was later machined to 10mm diameter and 405mm length. After machining, the connecting rod was later welded to the cutting blade.

4.2.3 Pulley

This was made from 750 mm x 750 mm wood. A conifer wood was selected because of the lower tendency to generate heat due to friction when in contact with the belt. The wood was machined on the wood lathe to a diameter of 300 mm with a tolerance of $\pm 0.005\text{mm}$ to allow the mating part move successfully.

4.2.4 Shafts (Driven and Driving)

Two pieces of rod length of 700 mm were cut for the driving shafts. This was later machined to 640mm and 250mm respectively. Turning of the two rod lengths to 25mm diameter was carried out on the lathe machine. Also a rod length of 400mm was cut for the driven shaft. This was reduced to 350 mm and turned on the lathe machine to a diameter of 25mm. Shallow drills and key ways were made on each rod as necessary to accommodate the lock screw and the key respectively.

4.2.5 Peeling blade

This was made from 1.5mm thickness mildsteel. 60mm length and 28mm breadth was cut, sharpened at one edge of the length and

well shaped cutting edge like a knife. The blade was then shaped in spherical curve like that of orange. The peeling blade was spring loaded in a pipe of 20mm diameter and 75 mm length and welded to the connecting rod.

4.2.6 Scotch yoke

A 3 mm flat plate was cut and machine to a diameter of 245 mm. Also a 25 mm diameter hole was drilled on the flat plate where the shaft from the pinwheel enters. The driving shaft holds the plate while the flat plate holds the yoke. A rod of 18 mm diameter was machined to 14mm diameter with length as 590 mm. A 170 mm length metal was welded to the rod after creating a small groove of 10mm x 160mm on it. A 0.75 mm diameter hole was drilled on the flat plate while one size 17 bolt and 2 nuts were used to fasten the rod which serve as the yoke to the plate .

4.2.7 Geneva wheel

This was made from 200mm x 200mm mild steel plate with 15mm thickness. A plate of diameter 145mm was marked out with the aid of a scribe and cut using oxyacetylene cutting flame. The diameter of the plate was later machined to 140mm on the lathe machine. The six slots and curvature of the Geneva wheel were made by the milling machine using 15mm end milling cutter. The wheel was bored to 24mm diameter.

4.2.8 Pin wheel

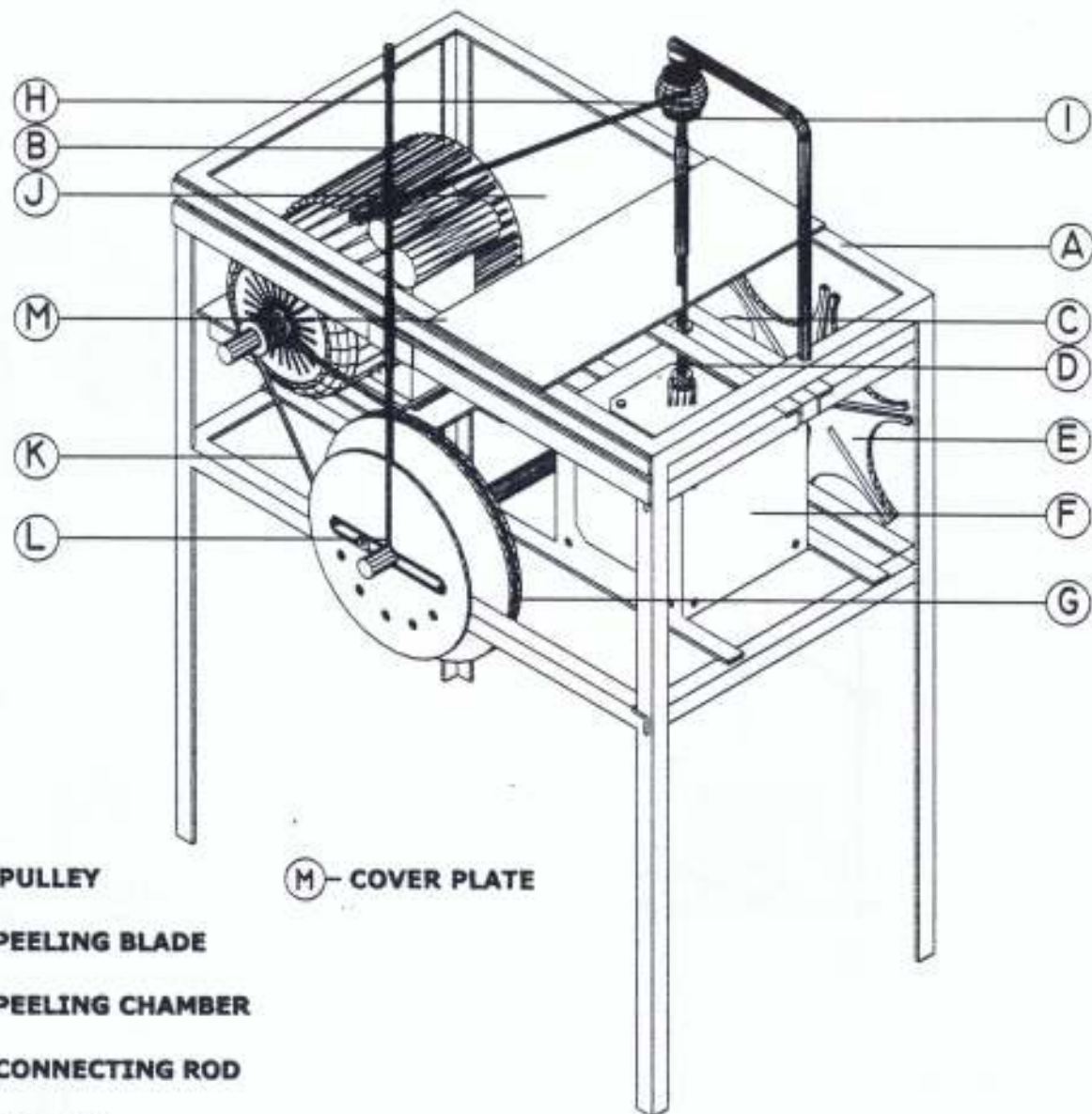
This was made from a 25mm thick mild steel plate. The mild steel plate was marked out at a center distance of 70mm and then cut into the required shape with the hacksaw and oxyacetylene gas cutting frame. The pin wheel was finally machined to precision on grinding machine, the two end arcs being 15mm and 40mm at the center distance apart. The 90° dwell curvature was made using the milling machine. The hole for the shaft was then bored to 25mm diameter.

4.3 ASSEMBLY OF THE MACHINE

The bought outs and fabricated components were carefully assembled together to produce the orange peeler. The isometric, orthographic and working drawings of the orange peeler are shown in Figures 24, 25 & 26. The assembled orange peeler is shown in Figure 27. The assembly of the machine parts follows the order described below:

- (1) A 38 mm x 38 mm angle iron was arranged, welded to shape and assembled together to form the machine frame. A base made of 2mm thickness mild steel sheet metal was also welded on top of the frame to serve as cover.
- (2) A 25mm diameter horizontal driving shaft from the pinwheel was pushed in through a bearing and allowed to go through the wooden pulley via another bearing to the scotch yoke assembly unit.
- (3) Another 25mm diameter horizontal driven shaft from the Geneva wheel was also pushed in through a bearing to enter the bevel gear box

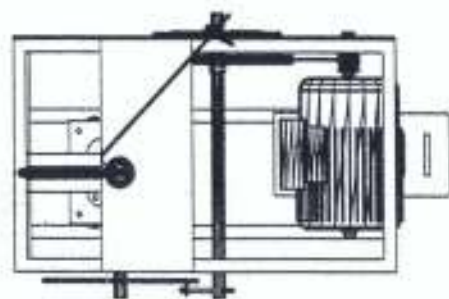
- (4) The bevel gear box was assembled together and properly positioned inside the frame. A small square of 12.5mm by 12.5mm flat plate was drilled at four corners and held tightly to the gear box by means of bolts and nuts.
- (5) A 25 mm diameter driving shaft was machined to link the bevel gear box vertically. The top of the shaft was spring loaded and covered with a cone like plate to enable it carry the clamp-like chamber for peeling various sizes of oranges.
- (6) A rod of diameter 25mm was cut and welded to form L-shaped which hold the upper jaw of the clamp.
- (7) The driven pulley was firmly secured and properly positioned to aligned with the driving pulley on the electric motor.
- (8) The Geneva wheel was arranged on a driven shaft while the pin wheel was arranged on the driving shaft. Both shafts were arranged and assembled parallel to each other. The pin wheel was made to be in contact (locking position) with the Geneva wheel.
- (9) The wheel and the yoke were assembled together. The shaft protruding from the pin wheel held the wheel while the wheel in turns held the yoke.
- (10) The scotch yoke mechanism which held the connecting rod and the welded peeling blade were assembled together. Provision for adjustment of the connecting rod was also made to ensure that different sizes of oranges placed in the chamber are peeled.



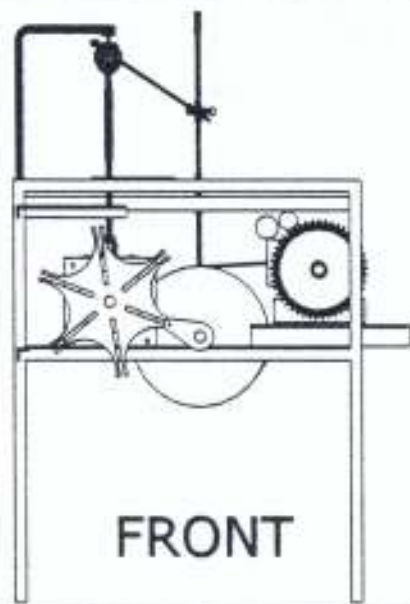
LEGEND

- | | | |
|--------------------|---------------------|-----------------|
| (A) MACHINE FRAME | (G) PULLEY | (M) COVER PLATE |
| (B) ELECTRIC MOTOR | (H) PEELING BLADE | |
| (C) PIN WHEEL | (I) PEELING CHAMBER | |
| (D) DRIVING SHAFT | (J) CONNECTING ROD | |
| (E) GENEVA WHEEL | (K) V-BELT | |
| (F) BEVEL GEAR BOX | (L) SCOTCH YOKE | |

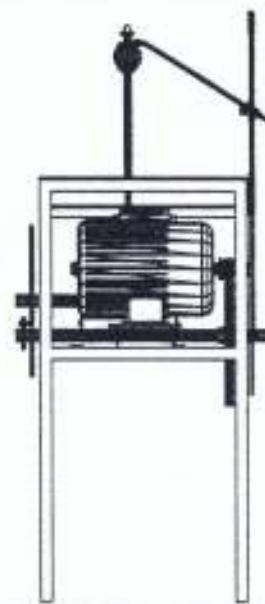
FIG 2₄: ISOMETRIC DRAWING OF THE ORANGE PEELER



PLAN



FRONT



SIDE

FIG 25: ORTHOGRAPHIC PROJECTION OF THE ORANGE PEELER

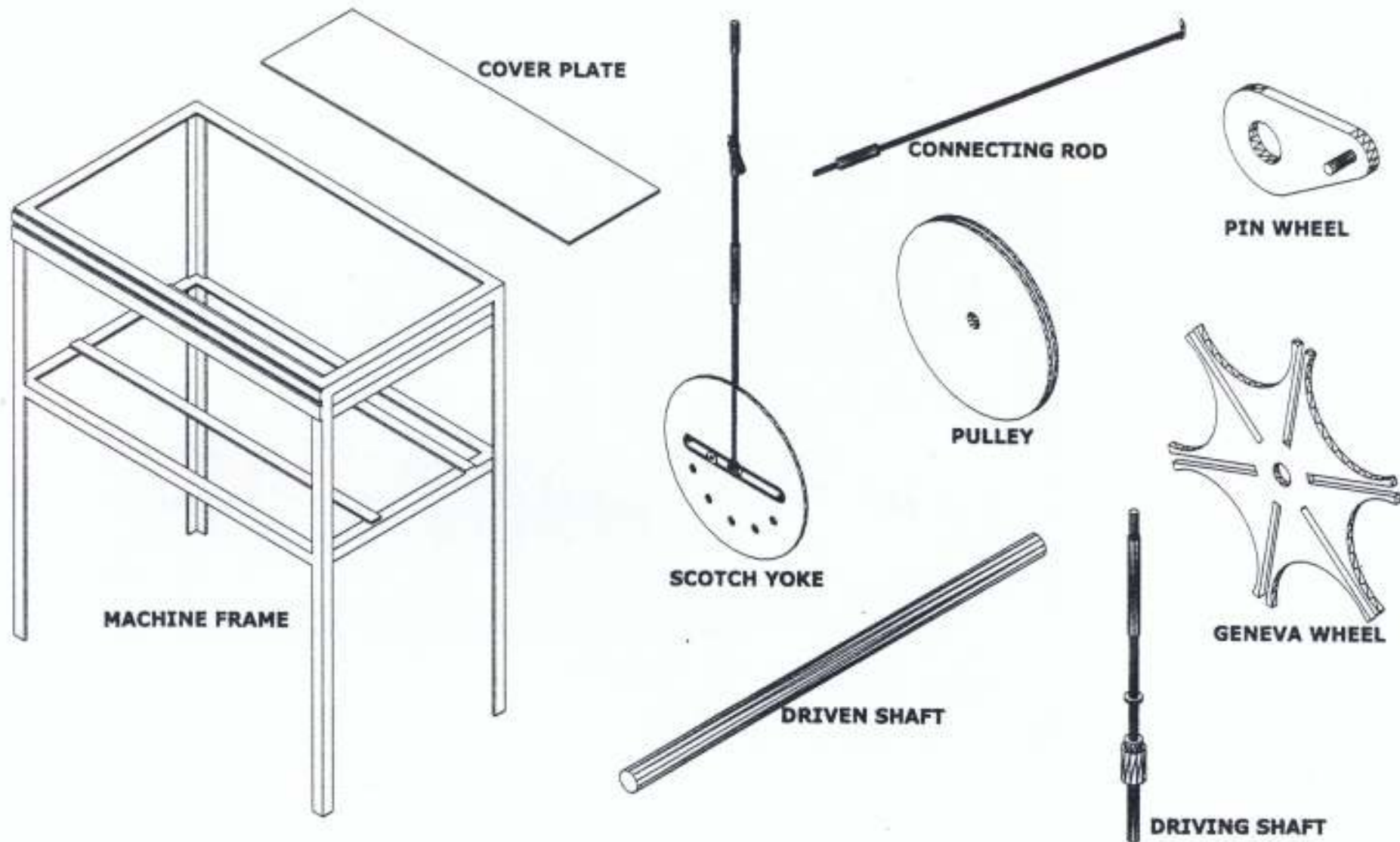


**FIG 26: THE WORKING DRAWING OF THE
ORANGE PEELER**



Figure 27: The Orange peeler

4.4 DESCRIPTION AND MECHANISM OF OPERATION OF THE MACHINE

The orange peeler consists of the following units: the frame which bears the entire load of the machine and it is also the mounting support for all the entire components of the machine; the peeling unit consisting of peeling blade, connecting rod, spring loaded chamber; the scotch yoke mechanism which consist of a rod, wheel and slider; the Geneva mechanism which consists of the Geneva wheel and a pin wheel; the transmission unit consisting of a One KW electric motor, a bevel gear, a wooden pulley and a V-belt. This unit also has driven and driving shafts supported on pillow block bearings.

The machine is powered by a single phase, One KW electric motor with a rotational speed of 1420rpm that is connected to an electric power source. The rotary power from the electric motor is transmitted via the V-belt and driven pulley. The rotary motion of the driven pulley enables motion to be transmitted through the horizontal driving shaft to the pinwheel with the aid of self aligning bearing. The pinwheel was constantly in contact (locking in and out position) with the Geneva wheel while intermittent motion was transmitted between them in quick succession. The intermittent motion was later transmitted from the driven shaft of the Geneva wheel to the gearbox with the aid of self aligning bearing. Further speed reduction was achieved in the bevel gear box from ratio 7:1 which was later transmitted at right angle to the

vertical driving shaft of the peeling chamber. Meanwhile the rotary motion of the driven pulley also rotates the scotch yoke mechanism. This was achieved through the extended horizontal driving shaft from the driven pulley via a self aligning bearing that rotates the wheel of the scotch yoke mechanism. This was achieved through the wheel of the scotch yoke through its pin transmits motion to the slider. As a result of the combination of the wheel and the slider, vertical oscillatory motion is transmitted through the scotch yoke to the connecting rod that holds the peeling blade to effect the required peeling longitudinally by shear method on the orange placed in the peeling chamber. In order to regulate the control on the thickness of peel removed for various sizes of orange, the peeling blade was spring loaded in a small pipe of 20mm diameter and 75mm length.

4.5 PRODUCTION COST ANALYSIS

Most of the components of the orange peeler was sourced and fabricated locally. The cost of the machine was evaluated based on the following cost items: the cost of bought out components and parts, the cost of the materials, and the cost of both the machining jobs and non-machining jobs. The production costs analysis of the machine is presented as shown in Table 4. The total cost of production of the machine amounted to twenty nine thousand and one hundred and forty naira only (N29,140.00)

Table 4. Production Cost Analysis**Components and parts fabricated**

Components and parts					Materials used for fabrication	
S/no	Name	Function	Specification	Quantity	Name	Dimension
1	Machine frame	Holds component together	640mmx510mm x 920mm	1.8m length	Angle iron	38mm x 38mm
2	Connecting rod	Transmit power to the cutting blade	450mm length, 20mm diameter	1	Mild steel rod	405mm length, 10mm diameter
3	Pulley	Power Transmission	300mm diameter	1	wood	750mmx750mm, 300mm diameter
4	Driving shaft	Rotate pulley, Geneva wheel and pin wheel	640mm, 250mm, 25mm diameter each	2	Shaft	800mm length, 30mm diameter
5	Driven shaft	Turn the bevel gear	350mm, 25mm diameter	1	Shaft	700mm, 30mm diameter
6	Peeling blade	Impacts the cutting action on the orange	60mm length, 1.5mm thickness	1	Mild steel	300mm length, 1.5mm thickness
7	Geneva wheel	Power transmission	140mm diameter plate, 15mm thickness, 6 slots	1	Mild steel plate	200m x 200mm, 15mm thickness
8	Pin wheel	Power transmission	25mm thickness mild steel, centre distance of 70mm, two end arcs of 15mm and 40mm	1	Mild steel	25mm thickness
9	Scotch-yoke	Power transmission	16mm diameter, 205mm diameter, 5mm thickness	1	Mild steel rod, mild steel plate	14mm diameter, 300mm diameter, 5mm thickness

A Cost of Bought out components and parts

S/no	Name	Functions	Specifications	Quantity	Unit cost (N)	Total cost (N)
1	Helical springs	Absorbing shocks, elastic deflections	20mm diameter, 70mm length, open ends, 24 no of coils	2	~~N~~ 200.00	~~N~~ 400.00
2	Pillow block bearing	Smooth rotation and proper alignment of shaft, reduce friction	25 mm internal diameter bore	3	N 2,500	N 7,500
3	V belt	Power transmission	A – Type	1	N150.00	N 150.00
4	Bevel gear	Power transmission	Ratio of teeth 1:7	1	N3,300	N3,300.000
Sub Total						N11,350.00

B Cost of materials (Not including the bought outs in Section A)

S/no	Materials	Size of a piece	Quantity required	Unit cost (N)	Total cost (N)
1	Angle iron	38mm x 38mm	1.8m length	~~N~~ 1,200.00	~~N~~ 1,200.00
2	Mild steel sheet	1.5mm thickness & 5mm thickness	650mm x 485mm	N4, 000.00	N500.00
3	Wood	Hard wood, 300mm diameter	300mm x 300mm	N 1,200.00	N200.00
4	Electrodes	Guage 12	1 packet	N1,100.00	N1,100.00
5	Hack saw blades	-	2 nos	N120.00	N240.00
6	Bolt and Nuts	M6, M16, & M12	6, 8, 10 hole sizes	N5, N10, N15	N200.00
7	High speed steel rods	16mm diameter	1050mm	N1,500.00	N150.00
8	Grinding disc	180 mm diameter	2	N250.00	N500.00
9	Paint	-	1 litre	N1,500.00	N1,500.00
10	Shaft	30mm diameter	800mm length	N500.00	N 500.00
11	Cutting disc	-	1	N 150.00	N150.00
Sub total					N6,240.00

C Machining Jobs

S/no	Materials	Type of job	Machine tools used	Time spent (min)	Labour cost/ hr (N)	Machine cost/ hr (N)	Total cost (N)
1	Shafts (30mm diameter)	Cutting & turning	Hacksaw, lathe machine	70	N1,500.00	N500.00	N2000.00
2	Wood	Cutting & turning	Wood lathe & carpenter saw	30	N300.00	N150.00	N450.00
3	Angle iron	Drilling, grinding, cutting & welding	Table drill machine, hacksaw	50	N2,000.00	N1000.00	N3,000.00
4	High speed steel rod	Size reduction	Arc welding & lathe machine	60	N350.00	N150.00	N500.00
5	Mild steel	Drilling, cutting & bending	Table drill machine, hack saw, oxyacetylene welding	40	N750.00	N250.00	N1000.00
6	Mild steel sheet (1.5mm thickness)	Cutting	Hand guillotine	10	N70.00	N30.00	N100.00
Sub- Total							N7,050.00

D Non-Machining Jobs

S/no	Job	Time spent (hr)	Labour cost/hr (N)	Equipment cost/hr (N)	Total cost(N)
1	Cutting	12	N400.00	N100.00	N500.00
2	Welding (Arc and gas)	10	N1,000.00	N1,000.00	N2,000.00
3	Grinding	6	N150.00	N50.00	N200.00
4	Marking out	6	N80.00	N20.00	N100.00
5	Punching	3	N150.00	N50.00	N200.00
6	Painting	½	N400.00	N100.00	N500.00
7	Machine assembly and test running	2	N800.00	N200.00	N1,000.00
Sub total					N4,500.00

Total cost of production = A + B + C + D

$$= \text{N} 11,350.00 + \text{N}6,240.00 + \text{N}7,050.00 + \text{N}4,500.00$$

$$= \text{N}29,140.00 \text{ excluding the cost of power source}$$

4.6 MAINTENANCE OF THE MACHINE

The following maintenance practices will ensure proper functioning of the Orange peeler:

1. All bolts and nuts used for fastening all the component parts must be constantly tightened and lubricated before and after peeling operation.
2. All bearings and the bevel gear box should be lubricated with soft grease after 500 hours of operation.
3. Always ensure that the belt tension is maintained. This can be done by checking the belt tension regularly to prevent loss of power.
4. The peeling blade must always be kept sharpen. Cleaning of the blade should always be carried out at the end of operation to avoid contamination and rust.

5. The machine must be kept in a cool and dry place. It must not be exposed to rainfall to prevent corrosion, malfunction or seizure of some parts.
6. It will also be a good practice to check the tightness of all bolts and nuts after every 10 hours of work, especially in the Geneva mechanism assembly unit where vibration is highest.

CHAPTER FIVE

RESULTS AND DISCUSSION



5.1 TESTING OF THE MACHINE

The power source of the machine was switched on and the machine was allowed to run for 60 minutes without any orange in place for peeling. The rotational speed of 1420rpm from the electric motor was smoothly transmitted from the 75mm diameter driving pulley via a V-belt to the 300mm diameter driven pulley. During the test run, the vibration was low since the materials for the driving and driven pulleys were made of mild steel and strong wooden materials respectively. There was no slippage during the operation because of adequate belt tension and correct alignment of pulleys.

The rotary motion of the driven pulley enables motion to be transmitted without any misalignment through the horizontal driving shaft to the pin wheel with the aid of a self-aligning bearing. Also the pinwheel was constantly in contact with the Geneva wheel while intermittent motion was smoothly transmitted between them in quick succession because of the proper alignment of the Geneva mechanism. It was possible to reduce the speed from 355rpm to 59.16rpm as a result of the transmission system of the Geneva wheel and the pin wheel.

The intermittent motion was also smoothly transmitted from the driven shaft of the Geneva wheel to the gearbox with the aid of a self-aligning bearing. There was no vibration as further speed reduction of

8.45 rpm was achieved in the gear box because of proper gear ratio selection. This speed was later transmitted smoothly at right angle to the vertical driving shaft of the peeling chamber.

The rotary motion of the driven pulley was also transmitted smoothly to the scotch yoke mechanism at a speed of 355 rpm. This was achieved with the aid of another self aligning bearing through the extended horizontal driving shaft. The wheel of the scotch yoke through its pin transmits motion smoothly to the slider. As a result of the combination of the wheel and the slider, vertical oscillatory motion is transmitted smoothly through the scotch yoke to the connecting rod that holds the peeling blade. There was no breakdown in transmission between mating members during the operation because suitable materials were selected for their fabrication.

5.2 TESTING OF THE MACHINE WITH SWEET ORANGES

After the machine has been test run and its operation was satisfactory, It was used for peeling parson brown variety of sweet oranges obtained from the Joff-ideal family farms at Owo in Ondo state taking into consideration their sizes and degrees of ripeness. The sweet oranges were later selected into shapes like spherical, oblong and those whose shapes cannot be described by any geometrical shape. Oranges that have some resemblance with spherical shapes were eventually selected and grouped together for peeling operation. Different degrees of

ripeness considered after the shape selection included yellow, pale yellow and green.

The orange selected for peeling was eventually placed in the peeling chamber. The chamber was spring loaded to accommodate variation in orange sizes. The peeling blade was adjusted to firmly be in contact with the orange outermost skin. The electric motor was switched on and the peeling operation commenced. The time taken for complete peeling of an orange was recorded using a stop watch. The weight of each orange before and after the peeling was noted and recorded.

After the peeling operation, it was observed that the peel remaining (peel retained) in the orange may have to be removed manually. The peel remaining was hand peeled with a blade and weighed on the triple beam balance. The weight obtained was later added to the weight of peel removed from machine to give the weight of total peel of orange. The results obtained during the peeling machine testing are shown in Table 5, 6 & 7.

Table 5: Results of the orange peeling machine testing for yellow samples of orange

Ripeness Of Orange	Weight of unpeeled Orange (Kg)	Weight of Orange peeled (Kg)	Time spent for peeling (min)	Weight of peel removed by machine (Kg)	weight of peel removed by hand (Kg)	weight of total peel of orange (Kg)
Yellow	0.205	0.19	2.30	0.011	0.004	0.015
	0.184	0.17	2.00	0.010	0.004	0.014
	0.164	0.15	2.06	0.008	0.005	0.014
	0.249	0.23	2.30	0.014	0.005	0.019
	0.216	0.20	2.00	0.012	0.004	0.016
	0.195	0.18	1.68	0.012	0.003	0.015
	0.243	0.23	2.18	0.009	0.004	0.013
	0.277	0.26	2.21	0.012	0.005	0.017
	0.268	0.25	2.10	0.013	0.005	0.018
	0.276	0.26	2.30	0.011	0.005	0.016
	0.186	0.17	2.00	0.011	0.005	0.016
	0.260	0.24	2.22	0.012	0.008	0.020
	0.154	0.14	2.08	0.010	0.004	0.014
	0.173	0.16	1.88	0.008	0.005	0.013
	0.218	0.20	1.68	0.012	0.006	0.018
	0.197	0.18	2.22	0.012	0.005	0.017
	0.280	0.26	2.24	0.013	0.007	0.020
	0.260	0.24	2.21	0.014	0.006	0.020
	0.220	0.20	2.10	0.015	0.005	0.020
	0.222	0.20	2.60	0.016	0.006	0.020

Table 6: Results of the orange peeling machine testing for pale yellow samples of orange

Ripeness of Orange	Weight of unpeeled Orange (Kg)	Weight of Orange peeled (Kg)	Time spent for peeling (min)	Weight of peel removed by machine (Kg)	weight of peel removed by hand (Kg)	weight of total peel of orange (Kg)
Pale	0.175	0.16	2.30	0.010	0.004	0.015
Yellow	0.226	0.21	2.22	0.011	0.005	0.016
	0.184	0.17	2.00	0.009	0.005	0.014
	0.182	0.17	2.10	0.008	0.004	0.012
	0.199	0.18	1.58	0.013	0.006	0.019
	0.193	0.18	2.00	0.009	0.004	0.013
	0.220	0.20	2.22	0.013	0.007	0.020
	0.252	0.23	2.21	0.014	0.008	0.022
	0.200	0.18	2.10	0.014	0.006	0.020
	0.178	0.16	2.00	0.013	0.005	0.018
	0.230	0.21	2.45	0.014	0.006	0.020
	0.198	0.18	2.60	0.011	0.007	0.018
	0.290	0.27	2.24	0.013	0.007	0.020
	0.252	0.23	2.24	0.016	0.006	0.022
	0.300	0.28	2.48	0.014	0.006	0.020
	0.188	0.17	2.45	0.011	0.007	0.018
	0.237	0.22	2.46	0.012	0.005	0.017
	0.219	0.20	2.30	0.013	0.006	0.019
	0.246	0.23	2.21	0.011	0.005	0.016
	0.232	0.21	2.22	0.016	0.006	0.022

Table 7: Results of the orange peeling machine testing for green samples of orange

Ripeness of Orange	Weight of unpeeled Orange (Kg)	Weight of Orange peeled (Kg)	Time spent for peeling (min)	Weight of peel removed by machine (Kg)	weight of peel removed by hand (Kg)	weight of total peel of orange (Kg)
Green	0.219	0.20	2.24	0.015	0.004	0.019
	0.196	0.18	1.68	0.012	0.004	0.016
	0.195	0.18	2.22	0.011	0.004	0.015
	0.218	0.20	2.24	0.013	0.005	0.018
	0.224	0.21	2.30	0.010	0.004	0.014
	0.209	0.19	2.30	0.014	0.005	0.019
	0.221	0.21	2.24	0.012	0.007	0.011
	0.252	0.23	2.45	0.016	0.006	0.022
	0.226	0.21	2.22	0.011	0.005	0.016
	0.190	0.17	2.00	0.012	0.008	0.020
	0.221	0.20	2.10	0.014	0.007	0.021
	0.252	0.23	2.40	0.016	0.006	0.022
	0.195	0.18	2.22	0.011	0.004	0.015
	0.205	0.19	2.30	0.011	0.004	0.015
	0.183	0.17	2.00	0.009	0.004	0.013
	0.277	0.26	2.21	0.012	0.005	0.017
	0.209	0.19	2.30	0.014	0.005	0.019
	0.186	0.17	2.00	0.011	0.005	0.016
	0.218	0.20	2.24	0.013	0.005	0.018
	0.184	0.17	2.00	0.010	0.004	0.014

5.2.1 Determination of Machine Capacity and Functional Efficiency

Twenty (20) known weight of sweet oranges each of different degrees of ripeness were peeled using the machine, and the time taken to peel each batch were determined from a stop watch while discounting loading and unloading time.

The Machine capacity (kg/h) and the Functional efficiency (%) were determined from equations (1) and (2):

Machine capacity =
$$\frac{\text{Weight of orange peeled (kg)}}{\text{Time spent for peeling (h)}} \dots\dots\dots (1)$$

Functional efficiency =
$$\frac{\text{Weight of peel removed by machine} \times 100\%}{\text{Weight of total peel of orange}} \dots\dots\dots(2)$$

5.2.2 Discussion of Results obtained from the testing

The results of the machine capacities and functional efficiencies obtained for orange of different degrees of ripeness were determined as shown in Table 8, 9 & 10 respectively. The machine capacity and functional efficiency obtained for yellow samples of orange were 5.82Kg/h and 70.2% (Table 8). The machine capacity and functional efficiency obtained for pale yellow samples of orange were 5.45Kg/h and 67.9% (Table 9). The machine capacity and functional efficiency obtained for green samples of orange were 5.41Kg/h and 72.7% (Table 10).

Table 8. Machine Capacity and Functional efficiency for yellow samples of orange

	Replicates		Total	Mean
	A	B		
No of Oranges	10	10	20	10
Weight of unpeeled orange (Kg)	2.277	2.170	4.447	2.224
Weight of orange peeled (Kg)	2.120	1.990	4.110	2.055
Time spent for peeling (min)	21.13	21.23	42.36	21.18
Time spent for peeling (h)	0.352	0.354	0.706	0.353
Weight of peel removed by machine (Kg)	0.112	0.123	0.235	0.118
Weight of peel removed by hand (Kg)	0.044	0.057	0.101	0.051
Weight of total peel of orange(Kg)	0.157	0.178	0.335	0.168
Machine capacity (Kg/h)	6.02	5.62	11.64	5.82
Functional efficiency (%)	71.3	69.1	140.4	70.2

Table 9. Machine Capacity and Functional efficiency for pale yellow samples of orange

	Replicates		Total	Mean
	A	B		
No of Oranges	10	10	20	10
Weight of unpeeled orange (Kg)	2.009	2.392	4.401	2.201
Weight of orange peeled (Kg)	1.84	2.20	4.04	2.02
Time spent for peeling (min)	20.73	23.65	44.38	22.19
Time spent for peeling (h)	0.346	0.394	0.740	0.370
Weight of peel removed by machine (Kg)	0.114	0.131	0.245	0.123
Weight of peel removed by hand (Kg)	0.054	0.061	0.115	0.058
Weight of total peel of orange(Kg)	0.169	0.192	0.361	0.181
Machine capacity (Kg/h)	5.32	5.58	10.90	5.45
Functional efficiency (%)	67.5	68.2	135.7	67.9

Table 10. Machine Capacity and Functional efficiency for green samples of orange

	Replicates		Total	Mean
	A	B		
No of Oranges	10	10	20	2
Weight of unpeeled orange (Kg)	2.150	2.130	4.280	2.140
Weight of orange peeled (Kg)	1.98	1.96	3.94	1.97
Time spent for peeling (min)	21.89	21.77	43.66	21.83
Time spent for peeling (h)	0.365	0.363	0.728	0.364
Weight of peel removed by machine (Kg)	0.126	0.121	0.247	0.124
Weight of peel removed by hand (Kg)	0.052	0.049	0.101	0.051
Weight of total peel of orange(Kg)	0.170	0.170	0.340	0.170
Machine capacity (Kg/h)	5.42	5.40	10.82	5.41
Functional efficiency (%)	74.1	71.2	145.3	72.7

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

An orange peeler was designed, fabricated and tested. The operation of the machine is simple, easy to handle and serves to reduce the drudgery involved in manual peeling of oranges in Nigeria. The machine is powered by a 1420 rpm, one KW single phase electric motor and applies the intermittent motion of Geneva and Scotch yoke mechanisms to peel an orange by shear method. The machine capacity and functional efficiency obtained for yellow samples of oranges were 5.82Kg/h and 70.2%, the machine capacity and functional efficiency obtained for pale yellow samples of orange were 5.45Kg/h and 67.9%, and the machine capacity and functional efficiency obtained for green samples of orange were 5.41Kg/h and 72.7%. The performance of the machine when tested was satisfactory. Further research work should be carried out on how the orange peeler could be optimized using these mechanisms for continuous or batch process method of peeling.

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LIST OF APPENDICES

APPENDIX 1

DESIGN OF THE HELICAL SPRING

Engineering Design guides on Helical Springs, prepared by the Spring Research Association (1974), United Kingdom was followed in the design of the Helical Spring.

Data required:

1. Maximum outside diameter = 30mm
2. Working deflection = 20mm
3. working load = 3.0N
4. Working length = 50mm
5. Type of helical spring ends = open ends
6. Material of spring = carbon steel.

1. To determine the spring rate

$$\text{Working deflection} = \frac{\text{working load}}{\text{Spring rate}}$$

$$\begin{aligned}\text{Spring rate} &= \frac{\text{Working load}}{\text{Working deflection}} \\ &= \frac{3.0}{20} = 0.15\text{N/mm}\end{aligned}$$

2. To determine the free length, $l_0 = \text{Working length} + \text{working deflection}$

$$= 50 + 20 = 70\text{mm}$$

3. To determine the deflection to solid = Working deflection + 15% of

$$\text{working deflection} = 20 + \frac{15}{100} \times 20$$

$$= 20 + 0.15 \times 20 = 40.15\text{mm}$$

4. To determine the solid length, $l_e = \text{free length} - \text{deflection to solid}$.
 $= 70 - 40.15 = 29.85\text{mm}$
 $\therefore$ Solid length, $l_e = 29.85\text{mm}$
5. Selection of the mean coil diameter to be slightly less than the maximum
outside diameter = 25mm
6. Select the nearest suitable wire diameter from Table A5, Appendix
3. For a mean coil diameter of 25mm and a safe working load of at least
3.0N, the nearest suitable wire diameter = 1.25mm
7. Total number of coils, N
 $l_e = Nd$
 $\therefore N = \frac{l_e}{d} = \frac{29.85}{1.25} = 23.88\text{mm} \simeq 24$
8. Determining the number of working coils, n for springs with open ends =
 $= n = N$
 $n = 24$
9. To determine the product (S_n) of spring rate (S) and number of coils (n)
 $\therefore S_n = s \times n$
 $= 0.15 \times 24 = 3.6$
10. Range of mean coil diameter from Table A₁, Page 18 and 19 i.e. (1.25 -
3.6) = 3.55mm to 4.00mm.
11. Determining the range of outside diameter from the range of mean coil
diameter read in (10) i.e. outside diameter = mean coil diameter + wire
diameter = 4.00 + 1.25 = 5.25mm

12. The given outside diameter is not within the range from the table obtained in (11) above.

Thus using the formula to calculate the mean coil diameter, D:

$$S = \frac{GD^4}{8nD^3}$$

$$\text{i.e. } D = \frac{(GD^4)^{1/3}}{(8nD)}$$

Modulus of rigidity, G for carbon steel at room temperature = 79.3KN/mm²

$$= \left[\frac{79300 \times (1.25)^4}{8 \times 24 \times 0.15} \right]^{1/3}$$

$$= \left[\frac{193603.52}{28.8} \right]^{1/3}$$

$$= (6722.34)^{1/3} = 18.33$$

Then the outside diameter = mean coil diameter + wire diameter

$$18.33 + 1.25 = 19.58\text{mm}$$

13. The final basic design details:

- i Material of spring = Carbon- steel
- ii Type of ends = open ends
- iii Outside diameter = 19.58mm
- iv Total coils = 24
- v Free length = 70mm
- vi Spring rate = 0.15 N/ mm
- vii Working deflection = 20mm

APPENDIX 2

SELECTION OF BEARINGS

The procedure for the selection of ball bearing was according to the PSG Tech., Design data, 1982

1. Selection of bearing type: Deep groove ball bearing.
2. Radial load on bearing, $f_r = 7.5 \text{ N}$ (selected)
3. Axial load on bearing, $f_a = 3.0 \text{ N}$ (selected)
4. Equivalent load, P acting on the bearing, $p = (x f_r + y f_a) s$ -PSG Tech. Design data, (1982), where x = radial factor, y = thrust factor and s = service factor

From the table –,

$$x = 0.56, y = 1.4 \text{ and } s = 1.5$$

$$P = (x f_r + y f_a) s$$

$$= (0.56 \times 7.5 + 1.4 \times 3.0) 1.5$$

$$= (4.2 + 4.2) 1.5$$

$$= 12.6 \text{ N}$$

5. Required life of bearing, L_h in operating hours = 15,000 hrs – , PSG Tech., Design data, (1982)
6. Required life of bearing in million revolutions , L

$$L = \frac{\text{no of rev. per hr of shaft} \times \text{operating life of bearing in hrs}}{1 \text{ million}}$$

$$= \frac{85,200 \times 15,000}{1,000,000} = \frac{1,278,000,000}{1,000,000}$$

$$\therefore L = 1278$$

7. Dynamic capacity of bearing,

$$L = \left[\frac{C}{fr} \right]^n \quad \text{Where } n = 3 \text{ for ball bearing, } L = 1278, fr = 7.5N$$

Substituting these values in the equation

$$1278 = \left[\frac{C}{7.5} \right]^3 = \sqrt[3]{1278 \times 7.5} = 81.39000N$$

$$C \simeq 81.39N$$

8. Checking the dimension of the ball bearing from the table of the PSG Tech., Design data, (1982)

Series 60- Deep groove ball bearings

Bearing of basic design No (skf)	d mm	D _i Min	D mm	D ₂ Max	B mm	r mm	r ₁ mm	Basic Static C ₀	Capacity, kgf Dynamic C	Maximum permissible speed- rpm
6000	10	12	26	24	8	0.5	0.3	190	360	20000

Source: Design Data, PSG Tech., (1982)

Based on the above calculation and the selected diameter of shafts, a deep ball bearing of 25mm outside diameter was selected.

APPENDIX 3

DESIGN OF BELT AND PULLEY

Data Required:

1. Power to be transmitted = 1kw electric motor
2. Speed of the driving and driven pulley
 - a Speed of driving pulley, $n_1 = 1420$ rpm
 - b Speed of the driven pulley, $n_2 = ?$

Diameter of smaller (driving) pulley, $d_1 = 75$ mm (recommended)

Diameter of larger (driven) pulley, $d_2 = 300$ mm (selected)

$$n_1 d_1 = n_2 d_2$$

$$1420 \times 75 = n_2 \times 300$$

$$= \frac{1420 \times 75}{300} = \frac{106500}{300} = 355 \text{rpm}$$

Design procedures:

- 1(i) Type of belt selected = A-type with power range of 0.5kw - 5kw as in Table (PSG Tech., design data, 1982)
- (ii) The diameter of the smaller pulley (which should not fall below the recommended minimum pulley pitch diameter as in Table (PSG Tech., design data, 1982) The recommended minimum pulley pitch diameter, $d_p = 75$ mm

$$\therefore d = 75 \text{mm}$$

2. Calculation of belt speed

$$\text{Belt speed (s)} = \pi d_p n \text{ (m/sec)}$$

$$= \pi (0.075) \times \frac{1420}{60} = 5.58 \text{m/sec}$$

3. Determining the speed ratio range, $\frac{D}{d}$, using $i = \frac{D}{d} = \frac{n_1}{n_2}$ where $\phi = 0.98$

$$\frac{n_1}{n_2} < 9 \text{ -- (PSG Tech. design data, 1982)}$$

$$\begin{aligned} \text{Speed ratio range, } i &= \frac{n_1}{n_2} = \frac{1420}{355} (0.98) = 3.92 \\ &= \text{Speed ratio} = 4 \end{aligned}$$

4. The value of the Small diameter factor to account for variation of arc of contact, F_b as in Table = 1.14 (PSG Tech. design data, 1982)
5. To calculate the equivalent Pitch diameter, $d_e = d_p \times F_b$ - (PSG Tech. design data, 1982) = $0.075 \times 1.14 = 0.0855\text{m} = 85.5\text{mm} = 86\text{mm}$
6. Determination of the diameter of the larger pulley from $D = d \frac{n_1 \phi}{n_2}$ - (PSG Tech. design data, 1982) where $d = 75\text{mm}$, $n_1 = 1420\text{rpm}$, $n_2 = 355\text{rpm}$ $\phi = 0.98$

$$D = \frac{75 \times 1420}{355} \times 0.98 = \frac{104370}{355} = 294\text{mm}$$

$$\therefore D = 294\text{mm}$$

7. Reading the value of recommended $\frac{C}{D}$ ratio from the Table

$$\text{(PSG Tech. design data, 1982)} = 0.95$$

8. Calculation of C , Centre distance, mm
i.e. ratio $\left(\frac{C}{D} \times D \right) = 0.95 \times 294 = 279.3\text{mm}$

9. To calculate $C_{\min}$ and $C_{\max}$ (the nominal belt thickness, T is given in the Table. Nominal thickness (T) as obtained from the Table = 8mm - (PSG Tech. design data, 1982)

$$C_{\min} = 0.55 (D + d) + T \text{ (PSG Tech. design data, 1982)}$$

$$= 0.55 (294 + 0.75) + 8 =$$

$$0.55 (377) = 207.35 \text{ mm}$$

$$C_{\max} = 2(D + d) - (\text{PSG Tech. design data, 1982})$$

$$= 2(294 + 25) = 738 \text{ mm}$$

10. To calculate the Nominal pitch length of the belt, L

The Nominal pitch length of belt, L is given as $L = 2c + \frac{\pi}{2} (D + d) + \frac{(D - d)^2}{4c}$ (PSG Tech. design data, 1982)

$$= 2 \times 279.3 + \frac{\pi}{2} (294 + 75) + \frac{(294 - 75)^2}{4(279.3)}$$

$$= 558.6 + \frac{3.142}{2} (369) + \frac{(219)^2}{1117.2}$$

$$= 558.6 + \frac{1159.398}{2} + \frac{47961}{1117.2}$$

$$= 558.6 + 579.69 + 42.93$$

$$= 1181.22 \text{ mm}$$

- II. Selecting the closest nominal pitch length to the calculated value of L from the Table = 1204 mm — (PSG Tech. design data, 1982)

12. Calculation of the actual value of C, centre distance for a given belt length and diameter of pulleys

$$C = A + \sqrt{A^2 - B} \quad \text{— (PSG Tech. design data, 1982)}$$

$$\text{Where } A = \frac{L}{4} - \pi \cdot \frac{D + d}{8} = \frac{1204}{4} - \pi \cdot \frac{(294 + 75)}{8}$$

$$= 301 - \frac{1159.398}{8} = 301 - 144.92 = 156.08 \text{ mm.}$$

$$\therefore A = 156.08 \text{ mm}$$

$$B = \frac{(D-d)^2}{8} = \frac{(294-75)^2}{8} = \frac{(219)^2}{8} = \frac{47961}{8} = 5995.13\text{mm}$$

$$\therefore B = 5995.13\text{mm}$$

$$C = A + \sqrt{A^2 - B}$$

$$= 156.08 + \sqrt{156.08^2 - 5995.13}$$

$$= 156.08 + \sqrt{24360.9664 - 5995.13}$$

$$= 156.08 + \sqrt{18365.8364}$$

$$= 156.08 + 135.52 = 291.6\text{mm}$$

$$\therefore C = 291.6\text{mm}$$

13. Check that $C_{\min} \leq C \leq C_{\max}$

$$207.35\text{mm} \leq 291.6\text{mm} \leq 738\text{mm} \text{ (the condition holds)}$$

14. Reading the value of the correction factor for industrial value, f_a from the Table.

The correcting factor, f_a for individual Service, $f_a = 1.0$ - (PSG Tech. design data, 1982)

15. The maximum power in kw which the A type V-belt can transmit is given

$$\text{by the formular } P(\text{Kw}) = \left(0.45S^{-0.09} - \frac{19.62}{de} - 0.765 \times 10^{-4} S^2 \right) S$$

- (PSG Tech. design data, 1982)

$$= \left([0.45(5.58)^{-0.09} - \frac{19.62}{0.86} - 0.765 \times 10^{-4} (5.58)^2] \right) 5.58$$

$$= [0.45(0.8566) - 0.2281 - 0.0000765(31.1364)] 5.58$$

$$= (0.38547 - 0.2281 - 0.002381934) 5.58$$

$$= (0.154988666) 5.58$$

$$\therefore P = 0.86\text{KW}$$

16. The ratings for V-belt in Kw for cross-section A-type as in the Table = 0.85.
17. From the table, the value of corrective factor for length, $f_c = 0.94$ – PSG Tech. design data, 1982)
18. The correcting factor for arc of contact, $F_d = 0.86$ - (PSG Tech. design data, 1982)
19. Number of belt, $N = \frac{P \times f_a}{k_w \times f_c \times f_d}$ (PSG Tech. design data, 1982)

P = Drive power (kw)=0.86

f_a =Correction factor according to service=1.0

k_w = Ratings of the V-belt=0.85

f_c = Correction factor for length =0.94

f_d = Correction factor for arc of contact=0.86

$$\therefore N = \frac{0.86 \times 1.0}{0.85 \times 0.94 \times 0.86} = \frac{0.86}{0.6871} = 1.251 = 1.25$$

Use 1 belt.

20. The corrected power = $P \times f_a$

$$= 0.86 \times 1.0$$

$$= 0.86 \text{ kw.}$$

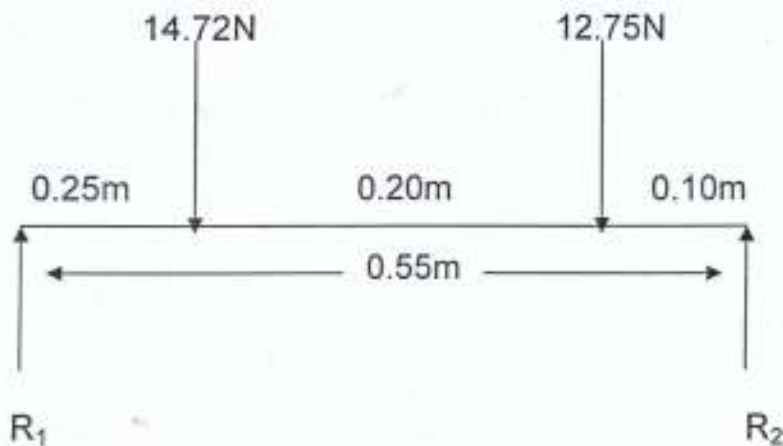
APPENDIX 4

DESIGN OF THE DRIVING SHAFTS

- a) The forces acting on the horizontal shaft were determined as follows:

$$F_1 = \text{Weight of pin wheel} = 1.5\text{kg} \times 9.81 = 14.72\text{N}$$

$$F_2 = \text{Weight of scotch yoke mechanism} = 1.3\text{kg} \times 9.81 = 12.75\text{N}$$



The reactions at R_1 and R_2 at the supports are first calculated.

By moments about R_2 :

$$R_1 \times 0.55 = 14.72 \times 0.45 + 12.75 \times 0.1$$

$$0.55R_1 = 5.724 + 1.275$$

$$0.55R_1 = 6.999$$

$$R_1 = \frac{6.999}{0.55} = 12.725$$

$$\therefore R_1 = 12.73\text{N and } R_2 = 14.72 + 12.75 - 12.73$$

$$\begin{aligned} R_2 &= 14.72 + 12.75 - 12.73 \\ &= 27.47 - 12.73 = 12.74\text{N} \end{aligned}$$

$$\therefore R_2 = 12.74\text{N}$$

Shearing force and Bending moment calculations

Shearing force:

Let x be the distance of the section from the left hand end

$$0 < x < 0.25, F = R_1 = 12.73 \text{ N}$$

$$0.25 < x < 0.45, F = R_1 - 14.72 = 12.73 - 14.72$$

$$= -1.99 \text{ N}$$

$$0.45 < x < 0.55, F = R_1 - 14.72 - 12.75 = 12.73 - 14.72 - 12.75$$

$$= -14.74 \text{ N}$$

Bending moment:

$$0 < x < 0.25, M = R_1 x = 12.73 \times 0.25 = 3.1825 \text{ Nm}$$

$$0.25 < x < 0.45, M = R_1 x - 14.72 (x - 0.25) =$$

$$= 12.73 \times 0.25 - 14.72 (0.45 - 0.25) = 3.1825 - 14.72 (0.2)$$

$$= 3.1825 - 2.944 = 0.2385 \text{ Nm}$$

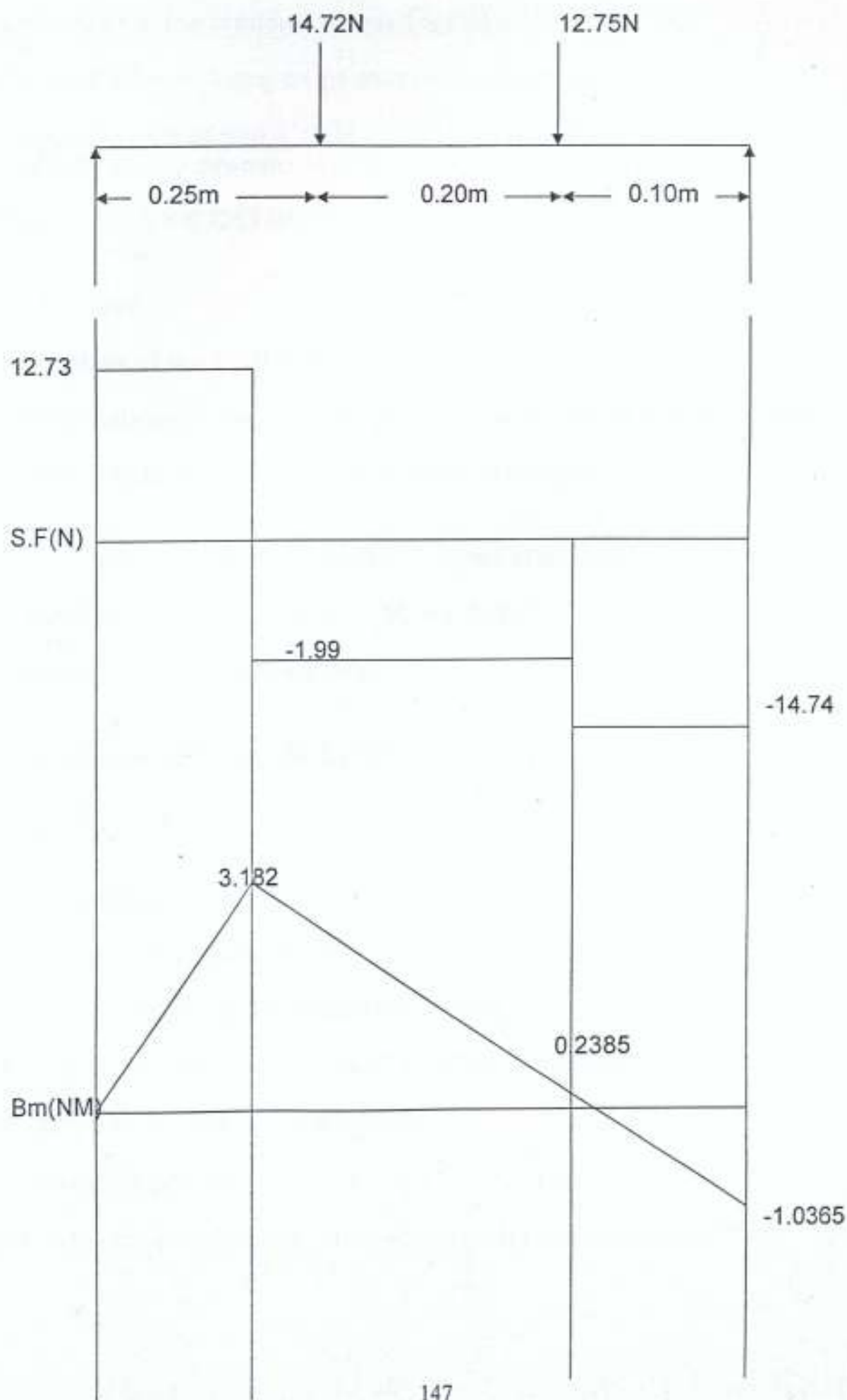
$$0.45 < x < 0.55, M = R_1 x - 14.72 (x - 0.25) - 12.75 (x - 0.45)$$

$$= 12.73 \times 0.25 - 14.72 (0.45 - 0.25) - 12.75 (0.55 - 0.45)$$

$$= 3.1825 - 14.72 (0.2) - 12.75 (0.1)$$

$$= 3.1825 - 2.944 - 1.275$$

$$= -1.0365 \text{ Nm}$$



Determination of the torsional moment acting on the shaft

The torsional moment acting on the shaft can be determined from

$$M_t = \frac{k_w \times 1000 \times 60}{2\pi \text{ rev/mm}} = \frac{9550 \times k_w}{\text{rev/mm}} \text{ (Nm)} - \quad (\text{Hall et al., 19 80})$$

$$= \frac{9550 \times 1}{1420} = \frac{9550}{1420} = 6.7253 \text{ Nm}$$

$$\therefore M_t = 6.73 \text{ Nm}$$

Determination of the shaft diameter

In order to determine the shaft diameter for a shaft having little or no axial loading, the ASME shaft design Code equation reduces to

$$d^3 = \frac{16}{\pi S_s} \sqrt{[(k_b M_b)^2 + (k_t M_t)^2]} - (\text{Hall et al., 1980})$$

$$S_s = 55 \text{ MN/m}^2 \quad k_b = 1.5, \quad k_t = 1.0, \quad n = 3, \quad M_b = 3.1825 \text{ Nm}, \quad M_t = 6.73 \text{ Nm}$$

Substituting into the ASME equation

$$\begin{aligned} d^3 &= \frac{16}{3.142 (55 \times 10^6)} \sqrt{[(1.5 \times 3.1825)^2 + (1.0 \times 6.73)^2]} \\ &= \frac{16}{172810000} \sqrt{[(4.77375)^2 + (6.73)^2]} \\ &= 0.000000092 \sqrt{(22.7886) + (45.2929)} \\ d^3 &= 0.000000092 \sqrt{68.08158} \\ d^3 &= 0.000000092 \times 8.251156283 = 0.000000763 \\ d &= \sqrt[3]{0.000000763} = 0.009137797 \text{ m} = 0.009137 \text{ m} = 9.137 \times 3 \times n \\ &= 9.137 \times 3 = 27.1 \text{ mm} \quad \therefore d = 27 \text{ mm} \end{aligned}$$

Use 27mm shaft diameter

Based on the above calculation, the diameter of shaft selected was 25mm.

DESIGN OF THE DRIVING SHAFT

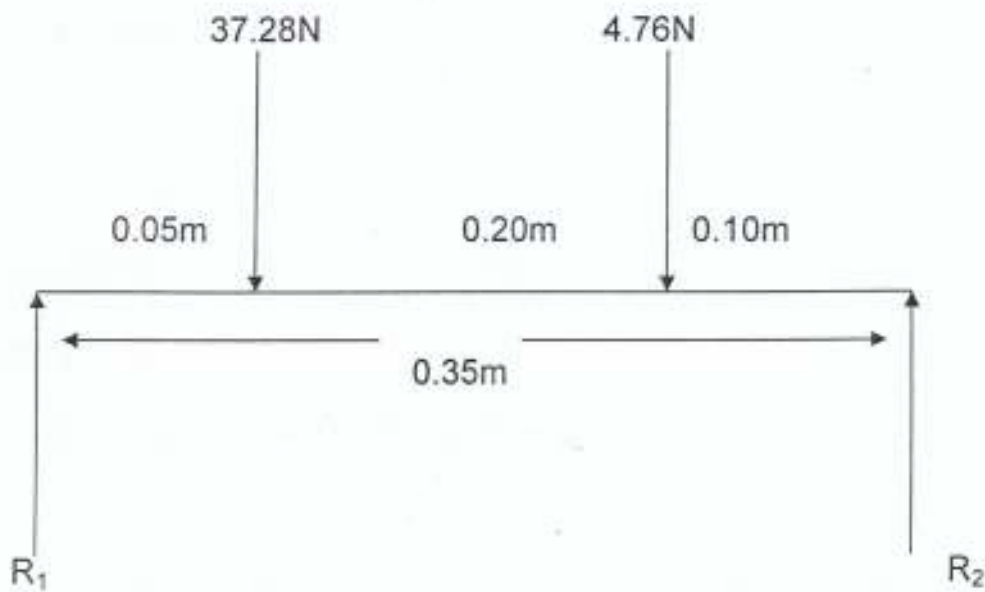
(b) The forces acting on the vertical shaft were determined as follows:

$$F_1 = \text{weight of the bevel gear} = 3.8\text{kg} \times 9.81 = 37.28\text{N}$$

$$F_2 = \text{weight of the peeling chamber} + \text{one orange}$$

$$= 0.485\text{kg} \times 9.81$$

$$= 4.76\text{N}$$



The reactions at R_1 and R_2 at the supports are first calculated.

By moments about R_2 :

$$R_1 \times 0.35 = 37.28 \times 0.25 + 4.76 \times 0.1$$

$$0.35R_1 = 9.32 + 0.476$$

$$0.35R_1 = 9.796$$

$$0.35R_1 = \frac{9.796}{0.35} = 27.988\text{N}$$

$$\therefore R_1 = 27.99\text{N} \text{ and } R_2 = 37.28 + 4.76 - 27.99$$

$$= 42.04 - 27.99$$

$$= 14.05\text{N}$$

$$\therefore R_2 = 14.05\text{N}$$

Shearing force and bending moment calculations

Shearing force:

Let x be the distance of the section from the left end

$$0 < x < 0.05, F = R_1 = 27.99\text{N}$$

$$0.05 < x < 0.20, F = R_1 - 37.28$$

$$= 27.99 - 37.28 = -9.29\text{N}$$

$$0.25 < x < 0.35, F = R_1 - 37.28 - 4.76$$

$$= 27.99 - 37.28 - 4.76 = -14.05\text{N}$$

Bending moment:

$$0 < x < 0.05, M = R_1 x = 27.99 \times 0.05 = 1.3995\text{Nm}$$

$$0.05 < x < 0.20, M = R_1 x - 37.28 (x - 0.05)$$

$$= 27.99 \times 0.05 - 37.28 (0.20 - 0.05) = 1.3995 - 37.28 (0.15)$$

$$= 1.3995 - 5.592$$

$$= -4.1925\text{Nm}$$

$$0.25 < x < 0.35, M = R_1 x - 37.28 (x - 0.05) - 4.76 (x - 0.25)$$

$$= 27.99 \times 0.05 - 37.28 (0.20 - 0.05) - 4.76 (0.35 - 0.25)$$

$$= 1.3995 - 37.28 (0.15) - 4.76 (0.1)$$

$$= 1.3995 - 5.592 - 0.476$$

$$= -4.6685\text{ Nm}$$

37.28N

4.76N

0.05m

0.20m

0.10m

27.99

S.F(N)

-9.29

-14.05

1.3995

Bm(NM)

-4.1925

-4.6685

Determination of the torsional moment acting on the shaft

The torsional moment acting on the shaft can be determined from

$$M_t = \frac{kw \times 1000 \times 60}{2\pi \text{ rev/min}} = \frac{9550 \times kw}{\text{rev/min}} \text{ (Nm)} \text{ --(Hall et al., 1980)}$$

$$= \frac{9550 \times 1}{304} = \frac{9550}{304} = 31.4144 \quad \therefore M_t = 31.41 \text{ Nm}$$

Determination of the shaft diameter

In order to determine the shaft diameter for a solid shaft having little or no axial loading, the ASME shaft design code equation reduces to

$$d^3 = \frac{16}{\pi S_s} \sqrt{[(k_b M_b)^2 + (K_t M_t)^2]} \text{ --(Hall et al., 1980)}$$

$$S_s = 55 \text{ MN/m}^2, K_b = 1.5, K_t = 1.0, n = 2.0, M_b = 1.3995, M_t = 31.41 \text{ Nm}$$

Substituting into the ASME equation

$$d^3 = \frac{16}{3.142 \times 55 \times 10^5} \sqrt{[(1.5 \times 1.3995)^2 + (1.0 \times 31.41)^2]}$$

$$= \frac{16}{172810000} \sqrt{[(2.09925)^2 + (31.42)^2]}$$

$$= 0.000000092 \sqrt{[(4.40685) + (986.5881)]}$$

$$= 0.000000092 \sqrt{(990.99495)}$$

$$= 0.000000092 \times 31.48007227$$

$$d^3 = 0.000002896$$

$$d = \sqrt[3]{0.000002896}$$

$$= 0.014254145 \text{ m} = 0.01425 \text{ m}$$

$$14.25 \text{ mm} \times n = 14.25 \times 2 = 28.5 \text{ mm} \quad d = 29 \text{ mm}$$

Use 29mm shaft diameter

Based on the above calculation, the diameter of shaft selected was 25mm

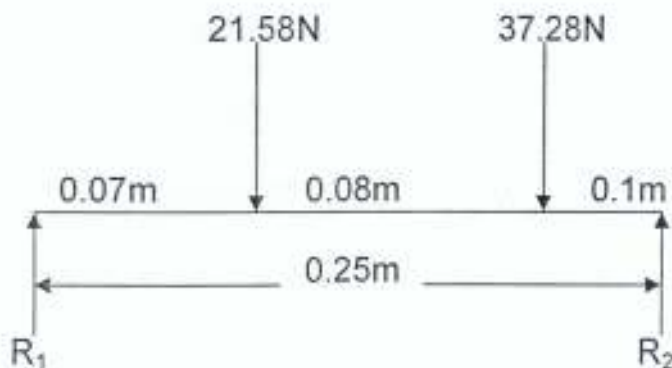
APPENDIX 5

DESIGN OF DRIVEN SHAFT

The forces acting on the horizontal shaft were determined as follows:

$$F_1 = \text{Weight of Geneva wheel} = 2.2\text{kg} \times 9.81 = 21.58\text{N}$$

$$F_2 = \text{Weight of bevel gear} = 3.8\text{kg} \times 9.81 = 37.28\text{N}$$



The reactions at R_1 and R_2 at the supports are first calculated:

By moments about R_2

$$R_1 \times 0.25 = 21.58 \times 0.15 + 37.28 \times 0.1$$

$$0.25R_1 = 3.237 + 3.728$$

$$0.25 R_1 = 3.237 + 3.728$$

$$0.25R_1 = 6.965$$

$$R_1 = \frac{6.965}{0.25} = 27.86\text{N}$$

$$\therefore R_1 = 27.86\text{N}$$

$$\text{and } R_2 = 21.58 + 37.28 - 27.86$$

$$= 58.86 - 27.86 = 31\text{N}$$

$$\therefore R_2 = 31\text{N}$$

Shearing force and Bending moment calculations

shearing force:

Let x be the distance of the section from the left hand end

$$0 < x < 0.07, F = R_1 = 27.86\text{N}$$

$$0.07 < x < 0.15, F = R_1 - 21.58$$

$$= 27.86 - 21.58$$

$$= 6.3\text{N}$$

$$0.15 < x < 0.25, F = R_1 - 21.58 - 37.28$$

$$= 27.86 - 21.58 - 37.28$$

$$= -31\text{N}$$

Bending Moment:

$$0 < x < 0.07, M = R_1 x = 27.86 \times 0.07 = 1.9502\text{Nm}$$

$$0.07 < x < 0.15, M = R_1 x - 21.58 (x - 0.07)$$

$$= 27.86 \times 0.07 - 21.58 (0.15 - 0.07)$$

$$= 1.9502 - 21.58 (0.08)$$

$$= 1.9502 - 1.7264$$

$$= 0.2238\text{Nm}$$

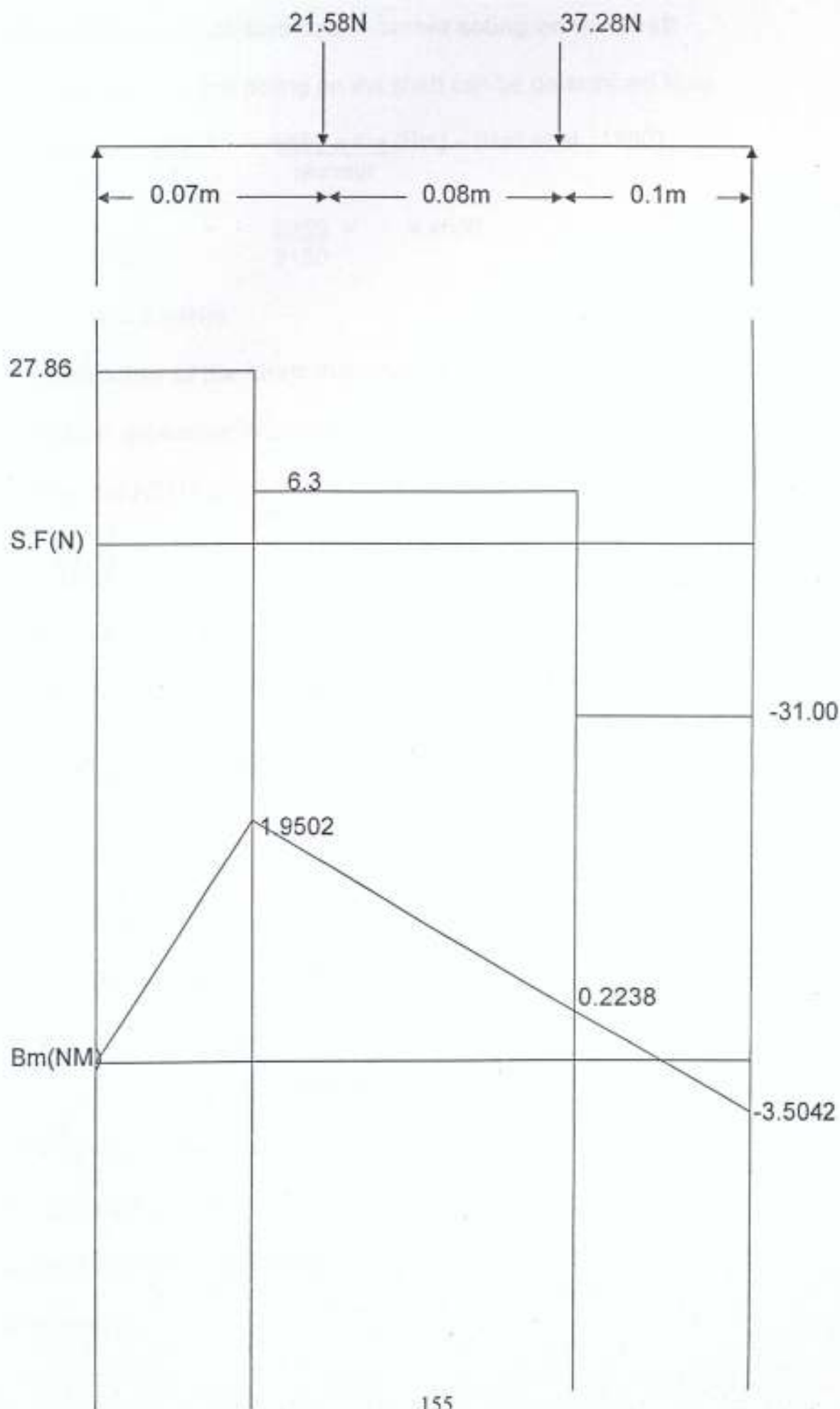
$$0.15 < x < 0.25, M = R_1 x - 21.58 (x - 0.07) - 37.28 (x - 0.15)$$

$$= 27.86 \times 0.07 - 21.58 (0.15 - 0.07) - 37.28 (0.25 - 0.15)$$

$$= 1.9502 - 21.58 (0.08) - 37.28 (0.1)$$

$$= 1.9502 - 1.7264 - 3.728$$

$$= -3.5042\text{Nm}$$



Determination of the torsional moment acting on the shaft

The torsional moment acting on the shaft can be determined from

$$M_t = \frac{K_w \times 1000 \times 60}{2\pi \text{ rev/min}} = \frac{9550 \times K_w}{\text{rev/min}} \text{ (Nm)} - \text{(Hall et al., 1980)}$$

$$\frac{9550 \times 1}{2130} = \frac{9550}{2130} = 4.4836$$

$$\therefore M_t = 4.48 \text{ Nm}$$

Determination of the shaft diameter

In order to determine the shaft diameter for a solid shaft having little or no axial loading, the ASME shaft design code equation reduces to

$$d^3 = \frac{16}{\pi S_s} \sqrt{[(K_b M_b)^2 + (K_t M_t)^2]} - \text{(Hall et al., 1980)}$$

$$S_s = 55 \text{ MN/m}^2, K_b = 1.5, K_t = 1.0, n = 3.0, M_b = 1.9502 \text{ N/m}, M_t = 4.48 \text{ Nm}$$

Substituting into the ASME equation

$$d^3 = \frac{16}{3.142 \times 55 \times 10^6} \sqrt{[(1.5 \times 1.9502)^2 + (1.0 \times 4.48)^2]}$$

$$= \frac{16}{172810000} \sqrt{[(2.9253)^2 + (4.48)^2]}$$

$$= 0.000000092 \sqrt{[(2.9253)^2 + (4.48)^2]}$$

$$= 0.000000092 \sqrt{(8.55738 + 20.0704)}$$

$$= 0.000000092 \sqrt{28.62778}$$

$$= 0.000000092 \times 5.350493435$$

$$d^3 = 0.000000492$$

$$d = \sqrt[3]{0.000000492}$$

$$= 0.007895759 \text{ m} = 0.07896 \text{ m}$$

$$= 7.896 \text{ mm}$$

$$7.896 \times n = 7.896 \times 3.5$$

$$27.64\text{mm}$$

Use 28mm shaft diameter

Based on the above calculation, the diameter of shaft selected was 25mm.

APPENDIX 6

DESIGN OF THE CONNECTING ROD

Data required:

Material selected for the connecting rod = mildsteel

Length of the rod (selected) = 405mm

Diameter of the rod (selected) = 10mm

Density of mildsteel = 7832kg/m^3 (Hall et al., 1980)

The rod is of circular section

Volume = Area x length of rod

$$= \pi \frac{(0.01)^2}{4} \times 0.405$$

$$= 0.00007855 \times 0.405$$

$$= 0.000031812\text{m}^3$$

Mass of the connecting rod = density x volume

$$= 7832 \times 0.000031812$$

$$= 0.249157458\text{kg}$$

Weight of the connecting rod = 0.249157458×9.81

$$= 2.444234663\text{N}$$

$$= 2.44\text{N}$$

APPENDIX 7

DESIGN OF THE PEELING BLADE

Material selected = mildsteel

Density of mild steel = 7832kg/m^3

Thickness of blade (selected) = 1.5mm

Length of the blade (selected) = 60mm

Breadth of the blade (selected) = 28mm

Selection was based on (Table1), the peel thickness of orange ranges between 1.05mm and 1.95mm

Area = length x breadth

$$= (0.06 \times 0.028)$$

$$= 0.00168\text{m}^2$$

Volume = Area x thickness

$$= 0.00168 \times 0.0015$$

$$= 0.00000252\text{m}^3$$

Mass of the blade = density x volume

$$= 7832 \times 0.00000252$$

$$= 0.01973664\text{Kg}$$

$$= 0.0197\text{Kg}$$

Weight of peeling blade = 0.0197×9.81

$$= 0.193257\text{N}$$

$$= 0.193\text{N}$$

APPENDIX 8

DESIGN OF STRAIGHT TOOTH BEVEL GEAR.

The procedure outlined by the PSG Tech. Design data, (1982) was followed in the following selections:

- (i) Selection of Gear Materials:

Pinion	Wheel
Steel	Steel

- (ii) Selection of Brinell hardness, HB of the materials

$$HB \leq 350$$

- (iii) Selection of tooth form = 20° full depth is common

Determination of the dimensions of straight tooth bevel gear parts

1. Determination of the dimensions of straight tooth Bevel gear parts was by following the procedure enumerated by PSG Tech., Design data, (1982)

- (i) Mean module, Mm (selected from the recommended series of modules as in Table = 2.5mm (preferred)

- (ii) Determination of the Number of teeth, Z in each gear

Selected number of teeth in Z_1 on pinion (driving gear) = 14

Selected number of teeth in Z_2 on crown wheel (driven gear) = 98

$$\text{Gear ratio, } i = \frac{Z_2}{Z_1} = \frac{98}{14} = 7$$

$\therefore$ Gear ratio, $i = 7:1$

- (iii) Selection of type of gear transmission, 4ly from the Table 13 (PSG Tech., Design Data 1982)

$$(\psi_y = \frac{R}{b} \text{ where } R = \text{cone distance, cm and } b = \text{face width, cm})$$

$\therefore \psi_y$ selected from the table = 4

(iv) Transverse module, M_t

$$\text{calculated from } M_t = \frac{M_m \psi_y}{\psi_y - 0.5}$$

$$= \frac{2.5(4)}{4 - 0.5} = \frac{10}{3.5} = 2.86 \text{ kgf/cm}$$

(v) Mean spiral angle, β_m

The standard preferred value for mean spiral angle = 35°

(vi) Normal module, M_n

$$\text{calculated from } M_n = M_t \cos \beta_m$$

$$= 2.86 \cos 35^\circ$$

$$= 2.34 \text{ mm}$$

(vii) Reference angle, δ

$$\text{Calculated from } \delta = \tan^{-1} i$$

$$\text{and } \delta_1 = 90^\circ - \delta_2$$

i as determined in (ii) = 7

$$\therefore \delta_1 = \tan^{-1} 7 = 81.87^\circ = 82^\circ$$

$$\text{Also } \delta_1 = 90^\circ - \delta_2$$

$$= 90^\circ - 8^\circ$$

$$\therefore \delta_2 = 8^\circ$$

(viii) Cone distance, R

$$\text{calculated from } R = 0.5 M_t \sqrt{Z_1^2 + Z_2^2}$$

$$= 0.5 (2.86) \sqrt{14^2 + 98^2}$$

$$\begin{aligned}
 &= \sqrt{1.43^2 \cdot 196 + 9604} \\
 &= 1.43 \sqrt{9800} \\
 &= 1.43 \times 98.99 = 141.555
 \end{aligned}$$

$$\therefore = 141.56 \text{ cm}$$

(ix) Reference diameter, d

calculated from $M_t Z$

$$d_1 = M_t Z_1 \quad : \quad d_2 = M_t Z_2$$

$$d_1 = 2.86 (14) \quad : \quad d_2 = 2.86 (98)$$

$$d_1 = 40.04 \text{ mm} \quad : \quad d_2 = 280.28 \text{ mm}$$

(x) Tip diameter, d_a

calculated from $d_{a1} = M_t (Z_1 + 2 \cos \delta_1)$ and

$$d_{a2} = M_t (Z_2 + 2 \cos \delta_2)$$

$$d_{a1} = 2.86 (14 + 2 \cos 82^\circ)$$

$$= 2.86 (14 + 0.2783)$$

$$= 2.86 (14.2983)$$

$$= 40.8359$$

$$\therefore d_{a1} = 40.84 \text{ mm}$$

$$d_{a2} = 2.86 (98 + 2 \cos 8^\circ)$$

$$= 2.86 (98 + 1.9805)$$

$$= 2.86 (99.9805)$$

$$\therefore d_{a2} = 285.944 \text{ mm}$$

(xi) Face width, b

calculated from $b = 0.3R$ or $10M_t$ (whichever is smallest)

$$b = 10(28.6) = 28.6\text{cm}$$

(xii) Number of teeth on crown wheel, Z_{cw}

$$\text{Calculated from } Z_{cw} = \frac{2R}{M_t}$$

$$= \frac{2(141.56)}{2.86} = \frac{283.12}{2.86} = 98.99 = 98$$

(xiii) Standard pressure angle, α

Selected standard pressure angle (preferred) = 20°

(xiv) Minimum number of teeth on pinion to avoid undercutting is

$$Z_u = \frac{2x \cos \delta}{\sin^2 \alpha} \quad (x = 1, \text{ For uncorrected gear})$$

$$Z_u = \frac{2(1) \cos 82^\circ}{\sin^2 20^\circ} = \frac{2(0.13917)}{0.11698}$$

$$= \frac{0.27834}{0.11698} = 2.379 = 2$$

(xv) Addendum angle, θ_a

$$\text{calculated from } \tan \theta_{a1} = \tan \theta_{a2} = \frac{M_t f_o}{R}$$

Taken height factor, $f_o = 1$ for standard gear tooth

$$\tan \theta_{a1} = \tan \theta_{a2} = \frac{2.86(1)}{141.56} = 0.020^\circ$$

(xvi) Taken radial clearance, $C = 0.25m$ for standard clearance

(xvii) Dedendum angle, θ_f

$$\tan \theta_{f1} = \tan \theta_{f2} = M_t \frac{(f_o + c)}{R}$$

$$\tan \theta_{f1} = \tan \theta_{f2} = \frac{2.86 (1 + 0.25)}{141.56}$$

$$= \frac{3.575}{141.56} = 0.025^{\circ}$$

(xviii) Tip angle, δ_a

calculated from $\delta_a = \delta + \theta_a$

$$= 82^{\circ} + 0.020 = 82.02^{\circ}$$

(xix) Root angle, δ_f

calculated from $\delta_f = \delta - \theta_f$

$$= 82^{\circ} - 0.025^{\circ} = 81.98^{\circ}$$

(xx) Addendum height, h_a

$$h_a = M_t$$

$$\therefore h_a = 2.86 \text{ kgf/cm}$$

(xxi) Dedendum height, h_f

$$h_f = 1.1236 M_t$$

$$= 1.1236 (2.86) = 3.213 \text{ cm}$$

(xxii) Tooth height, h

calculated from $h = h_a + h_f$

$$= 2.86 + 3.213 = 6.073 \text{ cm}$$

(xxiii) Working depth, h_w

calculated from $h_w = 2 M_t$

$$= 2 (2.87) = 5.72 \text{ cm}$$

(xxiv) Circular tooth thickness, S

calculated from

$$S_1 = \frac{\pi M_t}{2} (h_{a1} - h_{a2}) \tan \alpha + K M_t$$

$$\text{and } S_2 = \pi M_t - S_1$$

where the value of k , load concentration factor is selected from the Table for straight bevel gear to be $+ 0.075$ and for straight bevel gear,

$$h_{a1} = h_{a2} = h_a$$

$$S_1 = \frac{\pi (2.86)}{2} - (2.86) \tan 20^\circ + 0.075 (2.86)$$

$$= \frac{8.986}{2} - 2.86 (0.36397) + 0.2145$$

$$= 4.493 - 1.04095 + 0.2145 = 3.666 \text{ cm}$$

$$\therefore S_1 = 3.666 \text{ cm}$$

$$S_2 = \pi (2.86) - 3.666$$

$$= 8.98612 - 3.666$$

$$= 5.320 \text{ cm}$$

(xxv) Virtual number of teeth, Z_w

$$\text{calculated from } \frac{Z}{\cos \delta}$$

$$= \frac{14}{\cos 82^\circ} = \frac{14}{0.139} = 100.71$$

$$Z_w = 100$$

(xxvi) Diametral pitch, P_d

$$\text{Calculated from } P_d = \frac{Z}{d}$$

$$d \text{ is calculated in (ix) } = 40.04 \text{ cm}$$

$$\frac{14}{40.04} = 0.3497 \text{ mm}$$

(xxvii) Module, M

calculated from $M = \frac{d}{Z} = \frac{1}{Pd}$

and selecting from the Table

$$= \frac{40.04}{14} = \frac{1}{0.3497}$$

$$= 2.86\text{mm} = 2.86\text{mm}$$

$\therefore$ Selecting the recommended series of module from Table = 1.25mm

2. Determination of gear speed

Determination of Gear Speed based on $n_1 z_1 = n_2 z_2 (\pi d n)$

where d = reference or pitch diameter, n = no of revolutions of bevel gear (selected)

$$\therefore d = 40.04\text{mm}; n = 8.45\text{rpm}$$

substituting into $v = \pi d n$

$$= \pi (0.4004) \times \frac{8.45}{60}$$

$$= 0.1772\text{m/sec}$$

$$\therefore \text{Gear Speed} = 0.177\text{m/sec}$$

APPENDIX 9

DESIGN OF THE SCOTCH YOKE MECHANISM

Design parameters:

Mass of the scotch yoke mechanism = 1.3 Kg

Length of the yoke (selected) = 590mm

Wheel diameter (selected) = 245mm

Diameter of rod (selected) = 13mm.

The rotational speed of the scotch yoke

The rotational speed of the scotch yoke = πdn

d = wheel diameter = 245mm

n = rpm delivered at the scotch yoke mechanism = 355rpm (the same speed was delivered with that of belt and pulley drive)

Substituting in to the formular

$$= \pi (0.245) \times \frac{355}{60}$$

$$= \pi (0.245) \times 5.92$$

$$= 4.5571 \text{ m/sec}$$

$$= 4.56 \text{ m/sec}$$

Power developed by the scotch yoke mechanism

Force overcome = $1.3 \times 10 \text{ N}$

Distance (length of yoke) = 590mm = 0.59m

Work done (energy transferred) = $1.3 \times 10 \times 0.59$

Time (average for 10 strokes) = 12.6s

$$\text{Power} = \frac{\text{work done}}{\text{Time taken}}$$

$$= \frac{1.3 \times 10 \times 0.59}{12.6} = \frac{7.67}{12.6} = 0.60873 \text{ J/s}$$

$$= 0.609 \text{ J/s} = 6.09 \times 10^{-4} \text{ KW}$$

APPENDIX 10

DESIGN OF THE GENEVA MECHANISM

The procedure for the design of the Geneva mechanism was according to the PSG Tech., Design data, (1982).

Data Required:

(1) Speed of Geneva wheel, $n_d = \frac{355}{6} = 59.16\text{rpm}$

(2) Number of slots on the Geneva wheel, $z = 6$

Procedure for the design:

(1) Determination of the speed of the pin wheel, $n = 355\text{rpm}$

(6 revolutions of pin wheel = 1 revolution of Geneva wheel) – PSG Tech, Design data, (1982)

(2) Reading the External Geneva characteristics from the Table

Table 9: Design specifications for a 6 slot Geneva wheel

Z	α	β	ϵ	$\frac{r}{e}$	$\frac{R}{e}$	μ	$\frac{S_{min}}{e}$	ψ	v
6	30°	60°	2	0.5000	0.8660	1.7320	0.500	240°	0.3333

Source: PSG Tech., Design Data (1982)

(3) Selecting e such that $\frac{dw}{e} < 2 \left(1 - \sin \frac{\pi}{z} \right)$

to avoid the wheel overhanging the bearing.

e is selected to be 80mm

$$2 \left(1 - \sin \frac{\pi}{z} \right) = 2 \left(\frac{S_{min}}{e} \right)$$

From the Table 9, $\frac{S_{min}}{e} = 0.5000$

$$\frac{d_w}{e} < 2 \text{ (0.5000)}$$

$$\frac{dw}{e} < 1.0$$

$$\therefore \frac{dw}{e} < 1.0$$

- (4) r is calculated from the values of $\frac{r}{e}$ read in Table 9 and e selected to be 80mm

$$\frac{r}{e} = 0.5000$$

$$\frac{r}{80} = 0.5000$$

$$r = 0.5000 \times 80$$

$$r = 40\text{mm}$$

- (5) Calculation of Q from $\frac{\lambda (\cos \theta + \lambda^2)}{1 - 2 \lambda \cos \theta + \lambda^2} w$

Also can be determined from

$$\frac{W_G}{W_p} = \frac{\lambda (\cos \theta + \lambda)}{1 - 2 \lambda \cos \theta + \lambda^2} \quad \text{-----} \quad (\text{Artobolesky, 1979})$$

where $\frac{W_G}{W_p} = 1.00$ (as read from the external Geneva characteristics Table – PSG Tech, Design Data, 1982).

$$1.00 = \frac{0.5000 (\cos \theta - 0.5000)}{1 - 2 (0.5000 \cos \theta) + 0.5000^2}$$

$$1 - 2 (0.5000 \cos \theta) + 1.00 (0.5000)^2 = 0.5000 \cos \theta - 0.5000^2$$

$$2 (0.5000 \cos \theta) + 0.5000 \cos \theta = 1 + 0.5000^2 + 1.00 (0.5000)^2$$

$$[2(0.5000) + 0.5000] \cos \theta = 1 + 0.5000^2 + 1(0.5000)^2$$

$$\cos \theta = \frac{1 + 0.5000^2 + 1 (0.5000)^2}{2(0.5000) + 0.5000} = \frac{1.5}{1.5} = 1$$

$$\cos \theta = 1$$

$$\therefore \emptyset = 0$$

$$(6) \quad Q \text{ is calculated from } \tan Q = \frac{\lambda \sin \emptyset}{1 - \lambda \cos \emptyset} \quad \left(\lambda = \frac{r}{e} \right)$$

$$= \frac{0.5000 \sin 0}{1 - 0.5000 \cos 0} = \frac{0}{0.5000 \times 1} = \frac{0}{0.5000}$$

$$\tan Q = 0$$

$$Q = 0$$

$$(7) \quad \text{Calculation of } w = 2\pi n$$

$$= 2 \times \pi \times \frac{355}{60} = 37.20 \text{ rad/sec}$$

$$(8). \quad \text{Calculation of } w_d = 2\pi n_d$$

$$= 2 \times \pi \times \frac{2130}{60} = 223.09 \text{ rad/sec}$$

$$(9). \quad \text{Calculation of } \alpha_d = \pm \frac{\lambda (1 - \lambda^2) \sin \emptyset}{(1 - 2\lambda \cos \emptyset + \lambda^2)^2}$$

also using the relationship

$$\alpha_G = \pm \frac{\lambda (1 - \lambda^2) \sin \emptyset}{(1 - 2\lambda \cos \emptyset + \lambda^2)^2} \cdot W^2 p \quad (\text{Artobolesky, 1979})$$

$$= \pm \frac{0.5000 (1 - 0.5000^2) \sin 0}{(1 - 2 \times 0.5000 \cos 0 + 0.5000^2)} \times 4.700^2$$

$$= \pm \frac{0.5000 (1 - 0.25) \sin 0}{(1 - 1 \cos 0 + 0.25^2)} \times 22.09$$

$$= \pm \frac{0.5000 - 0.125 \sin 0}{0 \times 1 + 0.0625} (22.09)$$

$$= \pm \frac{0.5000}{0.0625} = \pm 8 \text{ rad/sec}$$

$$(10) \quad \text{calculation of } W_{dmax} = \frac{\lambda}{1 - \lambda} \cdot w$$

$$= \frac{0.5000}{1 - 0.5000} \cdot 37.20$$

$$= \frac{0.5000}{0.5000} \cdot 37.20$$

$$= 37.20 \text{ rad/sec}$$

(11) calculation of $\alpha_{do} = \pm w^2 \tan \frac{\pi}{z}$

$$= \pm (37.20)^2 \tan \frac{180}{6} \text{ (where } z = 6)$$

$$= \pm 1383.84 \tan 30^\circ$$

$$= \pm 1383.84 (0.57734)$$

$$= \pm 798.95 \text{ rad/sec}^2$$

(12) Calculation of $t = \frac{60}{n}$ seconds

$$= \frac{60}{355} = 0.1690 \text{ sec}$$

(13) Calculation of t_i from $v = \frac{t_i}{t} = \frac{e}{\pi} = \frac{Z-2}{2Z} < \frac{1}{2}$

v from Table 9 = 0.3333, $v = \frac{t_i}{t}$

$$= 0.3333 = \frac{t_i}{0.1690}$$

$$t_i = 0.3333 \times 0.1690$$

$$t_i = 0.0563 \text{ Sec}$$

(14) t_r is calculated from $\frac{t_r}{t} = \frac{Z+2}{2Z}$

$$\frac{t_r}{0.1690} = \frac{6+2}{2(6)}$$

$$\frac{t_r}{0.1690} = \frac{8}{12}$$

$$12t_r = 0.1690 \times 8$$

$$12t_r = 1.352$$

$$t_r = \frac{1.352}{12} = 0.1127 \text{ sec}$$

(15) R is calculated from $\mu = \frac{R}{r} = \cot \alpha$

$$\mu \text{ from Table 9} = 1.7320$$

r previously determined in No (4) 40mm

$$\mu = \frac{R}{r} = 1.7320 = \frac{R}{40}$$

$$R = 1.7320 \times 40$$

$$\therefore R = 69.28 \text{ mm}$$

(16) Calculation of $R' = \sqrt{R^2 + \left(\frac{r_p^2}{R} \right)}$

For a selected value of r_p

The selected value of $r_p = 100 \text{ mm}$

$$R' = 100 \sqrt{1 + \left(\frac{10^2}{69.28^2} \right)}$$

$$= 69.28 \sqrt{1 + \frac{100}{4799.7184}}$$

$$= 69.28 \sqrt{1 + 0.02083}$$

$$= 69.28 \sqrt{1.02083}$$

$$= 69.28 (1.01036)$$

$$= 69.997$$

$$R' = 69.99\text{mm}$$

- (17). Calculation $S_{\min}$ (from the value of $\frac{S_{\min}}{e}$ read in (2) and e selected in (3))

$$\frac{S_{\min}}{e} \text{ from Table 9} = 0.5000$$

$$e \text{ selected in (2)} = 80\text{mm}$$

$$\frac{S_{\min}}{80} = 0.5000$$

$$S_{\min} = 40\text{mm}$$

- (18). Selecting such that $S_{\min} < S \leq e (1 - \sin \alpha)$

$$\text{This becomes } S \leq e \left(1 - \sin \frac{\pi}{2} \right)$$

$$S \leq 80 (1 - 0.5000)$$

$$S \leq 80 (0.5000)$$

$$S = 40\text{mm}$$

APPENDIX 11

DETERMINATION OF THE POWER REQUIREMENT

The speed requirement for the machine = (summation of rpm's for the belt and pulley drive + Geneva Mechanism + Bevel gear)

$$= \left(\frac{1420}{4} + \frac{355}{6} + \frac{59.16}{7} \right) \text{ rpm}$$

$$= (355 + 59.16 + 8.45)$$

$$= 422.61 \text{ rpm}$$

The speed requirement determined = 422.61 rpm

Based on the above calculation, 1kw electric motor delivery a turning speed of 1420 rpm was selected to drive the machine.